Route Travel Time Estimation Using Floating Car Data

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Why is *travel time* important?

- Input for mobility decision making

- Required by ITS applications:
  - Travellers
  - Fleet management
  - Traffic control
  - City authorities
  - Etc.
Automatic Number Plate Recognition (ANPR) Routes in Stockholm

- Easy to process
- Expensive
- Infeasible for Large scale
- High maintenance
- Single point of failure
GPS probes
7.00 - 7.15 AM, 5 workdays

- Large scale coverage
- Distributed (fault tolerant)
- Low maintenance

- Needs preprocessing
- Noisy
- Infrequent
- Penetration rate?
- Biased
Path inference

GPS probes \rightarrow \text{digital road network} \rightarrow \text{finding the most likely trajectory (path inference)} \rightarrow \text{trajectory}
Frequent data

Sampling rate:
one per 10 seconds
Sparse data

Sampling rate:
1 probe every 2 minutes
Links and map-matched observations

- $l_1$
- $l_2$
- $l_3$
- $l_4$
- $l_5$
- $l_6$

**Legend:**
- **link**
- **node**
- **a pair of map-matched points**

**Distance (km):**
- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
Link travel time estimation: weighted average method

Step 1. allocate observed travel time to links

\[
  f_{l_i} = \frac{\text{length (} l_i \text{)}}{h_{l_i}}
\]

\[
  t_{l_i} = \frac{t_s}{f_s} f_{l_i}
\]

\[
  \frac{\text{length (} l_2 \text{)}}{h_{l_2}} \quad \frac{\text{length (} l_3 \text{)}}{h_{l_3}}
\]

\[
  s \quad \{t_1, t_2, l_1, l_2, l_3\}
\]

\[
  t_s \quad t_2-t_1
\]

\[
  h_l \quad \text{free-flow speed of link } l
\]

- link
- node
- map-matched point
- link-observation overlap
Birger Jarlsgatan
08:00 – 08:15
Travel time estimation: weighted average method

Step 2. Weighted average, variance etc. for link
Link-based TT estimation

Travel time allocation
\[ \tau_{ik} = \gamma_{ik} \tau_i \quad \gamma_{ik} = \frac{\rho_{ik} \ell_k}{\sum_{k'} \rho_{ik'} \ell_{k'}} \]

Scaling (normalizing)
\[ t_{ik} = \frac{1}{\rho_{ik}} \tau_{ik}. \]

Weighting, aggregation
\[ \bar{t}_k = \frac{\sum_i \rho_{ik} t_{ik}}{\sum_i \rho_{ik}} \]

Mean route travel time
\[ \bar{T} = \sum_k \alpha_k \bar{t}_k \]

\( \tau_i \) : i-th travel time observation
\( s_i \) : first time stamp of the i-th observation
\( \rho_{ik} \) : fraction of link k covered by observation i
\( \alpha_k \) : fraction of link k included in definition of the route
\( \beta_{ik} \) : fraction of a route link k covered by observation i
\( \ell_k \) : length of link k
Route: as a virtual link
Route-based TT estimation

Travel time allocation

\[ \tau_i^R = \theta_i \tau_i \]
\[ \theta_i = \frac{\sum_k \beta_{ik} \ell_k}{\sum_k \rho_{ik} \ell_k} \]

Scaling

\[ T_i = \omega_i \tau_i^R \]
\[ \omega_i = \frac{\sum_k \alpha_k \ell_k}{\sum_k \beta_{ik} \ell_k} \]

Weighting, aggregation

\[ \bar{T} = \frac{\sum_i \theta_i T_i / \omega_i}{\sum_i \theta_i / \omega_i} \]

---

\( \tau_i \) \( i \)-th travel time observation
\( s_i \) first time stamp of the \( i \)-th observation
\( \rho_{ik} \) fraction of link \( k \) covered by observation \( i \)
\( \alpha_k \) fraction of link \( k \) included in definition of the route
\( \beta_{ik} \) fraction of a route link \( k \) covered by observation \( i \)
\( \ell_k \) length of link \( k \)
Some sources of bias

- Incomplete Coverage of Route
- Influence of Adjacent Network
- Non-Uniform Coverage of Route
- Unknown Route Entry Time
- Missing data
Some bias corrections

- FCD Concatenation
- Time-Based Allocation, Scaling & Weighting
- Link Count Weighting
- Adjacent Network Coverage Threshold
- Route Entry Time Extrapolation
FCD concatenation
Time-based allocation

\[ \tau_i^R = \theta_i \tau_i \]

\[ \theta_i = \frac{\sum_k \beta_{ik} l_k}{\sum_k \rho_{ik} l_k} \]

\[ \tau_i^R = \phi_i \tau_i , \]

\[ \phi_i = \frac{\sum_k \beta_{ik} t_k^0}{\sum_k \rho_{ik} t_k^0} \]

\[ t_k^0 : \text{a prior link travel time} \]

This is expected to reduce the bias from side streets
Time-based scaling

The assumption of homogenous speed along the route can be relaxed, and the allocated travel time is also scaled according to the ratio of the average speeds on the overlapping part and the entire route.

\[ T_i = \omega_i \tau_i^R \]

\[ \omega_i = \frac{\sum_k \alpha_k l_k}{\sum_k \beta_{ik} l_k} \]

\[ T_i = \eta_i \tau_i^R \]

\[ \eta_i = \frac{\sum_k \alpha_k t_k^0}{\sum_k \beta_{ik} t_k^0} \]
Adjacent Network Coverage Threshold

Observations for which $\phi_i$ is less than some defined threshold $\phi_{\text{min}}$ (e.g., 0.75) are excluded from travel time estimation.
Route Entry Time Extrapolation

\[ s_i' = s_i + t_i^{(1)} - t_i^{(2)} \]

\[ t_i^{(1)} = \tau_i \left( \sum_{m \in M} \rho_{im} \ell_m \right) / \left( \sum_k \rho_{ik} \ell_k \right) \]

\[ t_i^{(2)} = \left( \sum_{n \in N} \alpha_{n} \ell_n \right) / \bar{v}_i \]

\( \bar{v}_i \) is the uniform speed of \( i \), e.g. \( \left( \sum_k \rho_{ik} \ell_k \right) / \tau_i \)
Mean TT of Route 70
(Norr Mlarstrand-Kungsholmstorg - Alviksplan)

![Graph showing travel time variations over the day for FCD and ANPR data.](image)
Median, 25th and 75th percentile
FCD VS. ANPR
Median, 25th and 75th percentile
FCD VS. ANPR

[Graph showing travel time (minute) vs. time of day with various lines representing different percentiles and means for both FCD and ANPR data.]
Taxi data bias

Mean TT of Route 4
(Valhallav gen/Odengatan – Albano)
More examples ...
More examples...

Mean TT of Route 89
(Norr Mårstrand-Kungsholmstorg - Fleminggatan/Pipersgatan)

- FCD
- ANPR

Travel time (minute)

Time of day

2013-10-09
KTH, Transport Science Dep., Mahmood Rahmani
Mean TT of Route 67
(Alviksplan - Fleminggatan/StEriksgatan)

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- FCD
- ANPR

Map of the route from Alviksplan to Fleminggatan/StEriksgatan.
Online application

- Create route (virtual link) on the fly and on demand
- Select the map-matched pairs
- Estimate route travel time distribution
Conclusion

• A non-parametric method for route travel time estimation using low-frequency FCD is presented

• Not only the mean but any statistics of the route travel time distribution

• Routes can be defined on the fly (online applications)

• Taxis may not be a representative sample of the overall vehicle fleet
References


Thank you!

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Using Floating Car Data

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