FUSION METHODS FOR AN MFD ESTIMATION

Verkehrsingenieurtag
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17. March 2016
Outline

- Introduction
- Experimental Setup
- Fusion Method
- Conclusion
Some Numbers…

91 %

CHF 100
Key Performance Indicator

Speed \( (v) \)  
Flow \( (q) \)  
Density \( (k) \)

Relation: \( q = kv \)
Fundamental Diagram

$q$ vs $k$

$q_{max}$

$k_{opt}$

Uncongested
Unqueued

Congested
Queued

$k_j$

$k$
Macro Fundamental Diagram (MFD)

**What?**
- relates *average* flow and density
- aggregated view of traffic (e.g. 5min)

**Why?**
- easy-to-use
- macroscopic control

**With?**
- loop detectors
- floating car data (FCD)
Does it exist?

Yokohama (J)

Zurich
Two Data Sources

- Already installed in links
- Average flow and density:
  \[ q_{t,MFD} = \frac{\sum_i q_i t_i}{\sum_i l_i} \quad k_{t,MFD} = \frac{\sum_i k_i t_i}{\sum_i l_i} \]

- GPS, mobile phones, etc.
- Eddie's generalized definitions:
  \[ q_{t,MFD} = \tilde{q}_t = \frac{d_{tot,t}}{LT} \quad k_{t,MFD} = \tilde{k}_t = \frac{t_{tot,t}}{LT} \]
Loop Detectors
Loop Detectors
Loop Detectors

Overestimation of density
Loop Detectors
Loop Detectors
Floating Car Data (FCD)
Floating Car Data (FCD)
Network Coverage: Example

Loop detectors: **loop coverage**
6/23 ≈ 26%

Mobile probes: **probe penetration rate**
- exact: 72/201 ≈ 36%
- estimated with 6 loops: 20/53 ≈ 38%
Errors of an Estimated MFD
Errors of an Estimated MFD

- Sum of the relative errors

\[ \Delta S_t(MFD, eMFD) = \frac{\Delta q_t}{q_{\text{real},t}} + \frac{\Delta k_t}{k_{\text{real},t}} \]

\[ \bar{\Delta S} = \frac{1}{m_t} \sum_t \Delta S_t(MFD, eMFD) \]

- Ortigosa et al.

\[ \Delta R_t(MFD, eMFD) = \begin{cases} 
\frac{k_t - k_{cr}}{k_{cr}} & \text{if } k_t < k_{cr} \\
\frac{k_t - k_{cr}}{k_j - k_{cr}} - \frac{k'_{cr}}{k'_{cr}} & \text{if } k_t > k_{cr}
\end{cases} \]

\[ \bar{\Delta R}(MFD, eMFD) = \frac{1}{m_t} \sum_t |\Delta R_t(MFD, eMFD)| \]
VISSIM
- 10x10
- one-way, 2 lanes, 120m
- DTA
- homogeneous demand
- 5 random seeds
- 4x 1 hour simulation

Network Coverage
- 30 levels in [3%-100%]
- 1000 subsets
- probe penetration rate estimated with loops

5x 900’000 eMFD vs 1 real MFD
VISSIM
- 2.6 km²
- 4 random seeds
- emulates city’s public transport priorization

Network Coverage
- 30 levels in [3%-100%]
- 1000 subsets
- probe penetration rate estimated with loops

4x 900’000 eMFD vs 1 real MFD
No Fusion

- estimation based on one source solely

\[
\hat{q} = \begin{cases} 
\frac{D_p}{\rho LT} & \text{for probes} \\
\bar{q}_{\text{loops}} = \frac{D_i}{\phi LT} & \text{for loops}
\end{cases}
\]

\[
\hat{k} = \begin{cases} 
\frac{T_p}{\rho LT} & \text{for probes} \\
\bar{k}_{\text{loops}} \approx \frac{T_i}{\phi LT} & \text{for loops}
\end{cases}
\]
Fusion Algorithm

Data Fusion Algorithm:

1. Separate network
   a. Sub-network loop detectors
   b. Sub-network mobile probes

2. Calculate average flows and densities

3. Weight the two sub-networks
Network Separation
Proposed Fusion Algorithm

- Weight according:
  - Loop detector coverage,
  - Square root of mobile probes coverage

Example @ 3% mobile probes and 30% loops

\[
\tilde{q} = \frac{\phi \hat{q}_l + \sqrt{\rho(1 - \phi)} \hat{q}_{p-l}}{\phi + \sqrt{\rho(1 - \phi)}}
\]

\[
\tilde{k} = \frac{\phi \hat{k}_l + \sqrt{\rho(1 - \phi)} \hat{k}_{p-l}}{\phi + \sqrt{\rho(1 - \phi)}}
\]
Conclusion

If loop detectors are well distributed within the links, our data fusion algorithm improves the estimated MFD significantly.
So what?
So what?
References

- Gayah, V. V. and Dixit, V. V. (2013). Using mobile probe data and the macroscopic fundamental diagram to estimate network densities. Transportation Research Record: Journal of the Transportation Research Board, 2390(1):76–86.
- Ortigosa, J., Menendez, M., and Tapia, H. (2014). Study on the number and location of measurement points for an MFD perimeter control scheme: a case study of Zurich. EURO
- cf. Also MSc. Thesis
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