Real-time Predictions for Light Rail Train Systems

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LRT predictions: IEEE ITSC 2014, Qingdao China
Motivation

- Passengers and operators
- Reduce travel and operational uncertainty

- Mixed-operations, crossings
- LRT travel time fluctuations
  - \( CV(\text{running time}) = 0.44 - 0.86 \ [0.08, 1.44] \)

- Lack of knowledge on
  - the accuracy and reliability of RTI systems in practice
  - exact train positioning predictions
Study approach and research questions

- Tracker, filter and **predictor**

- Common practice: predict based on either the remaining scheduled time or assuming a constant speed

- Incorporating instantaneous **vehicle position and speed** – remaining speed profile, acc-/deceleration, relation to design speed

- Evaluating the performance of a currently deployed RTI system
- Developing and testing two alternative prediction schemes for LRT

- A **time-series model at the link-level**
Prediction schemes

- **Constant-speed model**
  \[ \widetilde{\Delta t} = \frac{D-d_0}{v_o} \]

- **Design-speed model** – decomposition of vehicle link-based speed regime
  \[
  \widetilde{\Delta t} = \begin{cases} 
  0 < d_0 \leq d_1 & T - \sqrt{2d/a} \\
  d_1 < d_0 \leq D - d_2 & \frac{T_2 - \sqrt{2d/a}}{v_d} + t_2 \\
  D - d_2 \leq d_0 < D & \sqrt{2(D - d)/b} 
  \end{cases}
  \]

- **Speed-position model** – incorporating information on current speed
Trajectory scenarios

approaching the downstream station with a speed higher than the design speed (constant deceleration rate)
Trajectory scenarios

Travelled distance (m)

Designed speed (m/s)

$v_d$

$(d_0, v_0)$

Running faster than the design speed: (a) if the vehicle is too close to a downstream station (a constant deceleration rate $b$); (b) otherwise (first decelerate with rate $c$, maintain the design speed, decelerate with constant rate $b$)
Trajectory scenarios

slower than the design speed and is sufficiently far from the downstream station (acceleration with rate $a$, constant speed and deceleration with rate $b$)
Trajectory scenarios

running at a speed lower or equal to the design speed: (a) a sufficiently high speed (first roll and then break with deceleration rate $b$); (b) otherwise (accelerate with rate $a$, decelerate with rate $c$)
Remaining travel time:
Speed-position model

![Graph of Remaining travel time: Speed-position model](image)
Case study: Bybanen, Bergen, Norway

- Opened in 2010
- 9.8 km
- 25 crossings
- 4 tunnels
- 31,000 pass/day
- Mixed operations
- 6-12 dep/hr
- Dispatching control only
Implementation and Evaluation

• **AVLS** data from Feb 1–July 31, 2013 (train GPS, odometer records, activation of loops and track circuits)
• ∼0.5 million records
• Generate estimated arrival time at downstream stations

• Generate RTI

\[
\pi^p_s(\tau) = \Delta t^p_{k,m}(\tau) + \sum_{i=m}^{s-1} t^d_i + \sum_{i=m}^{s-1} t^r_i
\]

• Measures of performance
  • Short-term prediction error
    \[
e^p_{k,s+}(\tau) = \pi^a_{k,s+} - \pi^p_{k,s+}(\tau)
\]
  • RTI prediction error
    \[
e^p_s(\tau) = \pi^a_{k,S} - \pi^p_S(\tau)
\]
RTI prediction errors
Constant-speed model

83% within [-1min,+1min]

57% within [-30sec,+30sec]
Short-term prediction errors
Model comparison
Short-term prediction errors
Speed-position model

- Case 1: 16%
- Part A of Case 2: 6%
- Part B of Case 2: 30%
- Case 3: 39%
- Part A of Case 4: 8%
- Part B of Case 4: 1%

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Conclusions and future work

- Prediction **accuracy** (83%) > trunk bus lines [Stockholm, 64%] < metro [Boston, 90%]

89% for proposed prediction schemes
- Robust w.r.t. evolution along the line, under disturbances

- Inducing potential benefits for both passengers and operators
- A decision tree for choosing most appropriate prediction scheme
- Embed into speed control and guidance systems
- Addressing detected prediction shortfalls
Thank you! Questions?

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