Evaluation of horizontal and vertical queueing models: comparison to observed trajectory data in a signalized urban traffic network

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Objectives
- Introduce the formulation of the Vertical Cell Model (VCM), a cell-based implementation of a vertical queueing model for networks with interrupted flow that incorporates a simple representation of intra-link transit delay and finite link storage capacity.
- Validate this model against a set of ground-truth density and flow measurements derived from high-resolution vehicle trajectory observations on a real urban traffic network.
- Show that VCM performs equally as well as CTM relative to these ground-truth observations.

Vertical Cell Model (VCM)

Designed to simplify the intra-link dynamics of a typical CTM implementation, VCM represents the state of an urban road link as a set of “transit” cells and a single “queue” cell.

**VCM Link Model**

\[
\begin{align*}
\mathbf{v}^{i}(t+1) &= \mathbf{v}^{i}(t) + \mathbf{q}^{i}(t) - \mathbf{d}^{i}(t) \\
\mathbf{q}^{i}(t) &= \mathbf{v}^{i}(t) - \mathbf{d}^{i}(t)
\end{align*}
\]

Notably, the VCM link model is linear in terms of link arrivals and departures. Linear link dynamics improves computational efficiency and yields analytical benefits for theoretical estimation and control procedures.

**VCM Node Model**

\[
\begin{align*}
R_{l}(t) &= \mathbf{v}^{l}(t) \\
S_{l}(t) &= \mathbf{q}^{l}(t)
\end{align*}
\]

\[
\Delta t = 1 \text{ second.}
\]

**Model Implementation**

Both VCM and CTM were implemented in the Berkeley Advanced Traffic Simulation (BeATS) platform using the same network graph (Figure 3) and a cell size corresponding to \( \Delta t = 1 \text{ second.} \)

**Model Error**

Model error is more sensitive to (shared) misrepresentations of network geometry or physical parameters than to differences in the model dynamics.

**Results**

Figure 4: A comparison of modeled and observed link exit flows.

Figure 5: A photo of the Lankershim Blvd data collection site (top) and the graphical representation used in our modeling procedure (bottom).

Figure 6: Outflow error for CTM and VCM (relative to 5-second aggregated observations).

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**Data**

This study makes use of the high-resolution vehicle trajectory data obtained between four intersections of Lankershim Blvd, a busy arterial roadway in Los Angeles, California as part of the Next Generation Simulation Community (NGSIM) project (http://ngsim-community.org/).

- External demands were obtained by aggregating 5-second vehicle counts from the full set of trajectories at relevant network boundary locations.
- Intersection turn ratios were assumed fixed and set equal to the average turning proportion observed over the entire 30 minute data set.
- Signals were timed according to timing sheets provided in NGSIM data documentation.

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**Figure 1** An illustration of the VCM link model

**Figure 2** An illustration of the CTM link model

**Figure 3** A photo of the Lankershim Blvd data collection site (top) and the graphical representation used in our modeling procedure (bottom).