Model-based prediction of freeway traffic conditions using PeMS loop detector data
Connected Corridors 2020 Pilot

*Vehicles, Infrastructure and People*

Connected and Automated Corridor

- Connected and Automated Vehicles
- Connected Infrastructure
- Integrated Corridors
- Connected Travelers
Connected Corridors 2020 Pilot

*Vehicles, Infrastructure and People*

- Corridor decision support component:
  1. Estimation of current conditions
  2. Prediction of near-future conditions
  3. Generation of control advice for operators
Subcomponent Progress Report

Model-based prediction of freeway traffic conditions

1. Estimate current state of traffic along entire length of freeway, using PeMS loop detector data where available

2. Run calibrated model one hour forward in time, using predicted demands and “split ratios”(*)

(*) A “split ratio” is the fraction of mainline vehicles that exit the freeway at a particular offramp at a particular time.
Model building:
Freeway geometry
Model building: PeMS data for calibration

Selection criteria:
• Healthy detection
• Free flow downstream boundary,
• Sufficient congestion
• No major incidents
Model building:
Calibration of fundamental diagram parameters

- Calibration: Process of fitting fundamental diagram to many days of density/flow data from PeMS for each modeled network segment (link)
Model building:
Test and compare (10/15/2013)
Estimation of Current Traffic Conditions

All available new mainline data is assimilated...
Estimation of Current Traffic Conditions

...model is run forward 30 seconds...
...and updated estimated traffic state for entire length of freeway is calculated and recorded.
Estimation of Current Traffic Conditions

Every 30 seconds, all newly-available mainline data is assimilated, and the process repeats.
For one-hour predictions, we start with the current estimated freeway traffic conditions...
...and run the model forward for one hour, feeding it predicted boundary flows (# entering at each onramp) and split ratios (% of mainline exiting at each offramp).
How do we get onramp and offramp predictions to feed the model?

- We use clustered, averaged historical PeMS data at each location, tuned by PeMS data from the last hour.

See following sections for additional detail about PeMS-based Boundary Flow and Split Ratio predictions.
Estimation Run

Velocity

Density

0500 - 1200

0615 - 0715

http://gateway.path.berkeley.edu/~gregm/forecast/
Corridor-wide Traffic Prediction Architecture

PeMS Data Feed
- Raw PeMS Data
  - counts, occupancy

PeMS Filter
- PeMS Data Feed

Estimator
- Current traffic state
  - Boundary Flows
- Split Ratios

BF Pred
- Filtered PeMS Data
  - Speed, density, g-factor, flow

SR Pred

Predictor
- Model parameters
  - prediction horizon
  - time step length

CTM
- Predicted density over whole network

FD Calibration
- Fundamental Diagrams

Network
Boundary Flows

Boundary Flows

• **Predict near-future traffic inflow at network boundaries** to provide boundary condition for corridor-wide traffic flow predictor
  – On-ramp flow, mainline flow at beginning of corridor
  – For practical purposes: method must be fast and reliable

• Example of Loop Detector Data:

→ Traffic flow repeats daily and weekly
Boundary Flows – Algorithm

1. **Analyze historic profiles** (offline)
   - One profile = one day of measured flow data; use months of data
   - Classify by day-of-the-week
   - Calculate centroids as median profile for each class
   - Robust w.r.t. outliers

2. **Load prevailing partial profile and match to centroids** (online)
   - Prevailing profile = todays measured flow data from midnight to now
   - Load respective median centroid

3. **Forecast** based on best-matching cluster and prevailing profile (online)
   - By scaling historical profile according prevailing traffic flow of last hour
   - Robust w.r.t. to irregular traffic conditions
Boundary Flows – Results

Detector 1108717, day 17-Jan-2013 17:00:00

Flow [veh/h]

- prevailing profile
- predicted profile
- realized profile

Time

Fri
Mon
Sat
Sun

Thu
Tue
Wed
Boundary Flows – Current Research

• In Clustering Step:
  – Use K-Means
  ➔ Special days get special clusters, e.g. on-ramp near football stadium

• In Cluster-Matching Step:
  – Use nearest-neighbor, in conjunction with K-Means Clustering

• In Forecasting step:
  – Combine recent \(y\) and historical \(u\) data by Autoregressive Moving Average with Exogenous Input Model (ARMAX)
    \[
    y_{\text{pred}}(k+1) = b_1u(k+1) + b_2u(k) + b_1u(k-1)+ ... \\
    + a_0y(k) + a_1y(k-1)+ ... \\
    + c_0w(k) + c_1w(k-1)+ ...
    \]
    \(y_{\text{pred}}\): prediction; \(y\): recent data; \(u\): centroid; \(w\): estimation residual; \(k\): time step; \(a, b, c\): ARMAX parameters

  ➔ Closer prediction of boundary flow

Split Ratio Prediction
Split Ratio (SR)

• What is SR
  – The proportion of flow heading to different directions at diverging nodes

• Why predict SR
  – A necessary part of traffic prediction based on cell transmission model (macroscopic simulation)
  – Models origin-destination together with boundary flows
SR Prediction

• Input:
  – Historical SR profiles
    • e.g. over one year
  – Prediction horizon
    • e.g., over 1 hour

• Output:
  – Predicted SR for the given horizon
SR Prediction

- Current algorithm
  - Cluster SR by day of week
  - Calculate the median of SR within each cluster
  - Use the cluster median as the prediction

<table>
<thead>
<tr>
<th>Off-ramp Flow RMSE [veh/hr]</th>
<th>Overall</th>
<th>In congestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Deployment</td>
<td>69</td>
<td>258</td>
</tr>
<tr>
<td>New Model (work in progress)</td>
<td>63</td>
<td>172</td>
</tr>
</tbody>
</table>
More details on new model

OK to skip
SR Prediction

• Known issue
  – Diversion increases significantly (therefore poor prediction) when mainline is congested
SR Prediction

- Augmented (dynamic) algorithm
  - Cluster SR by day of week
  - Adjust SR with mainline occupancy
  - Calculate the median of the adjusted SR within each cluster
  - Adjust the cluster median with mainline occupancy as the prediction
SR Prediction

- Known issue
  - Diversion during accident-induced congestion is more severe than that during recurrent congestion → underprediction