Modeling, Simulation, Analysis and Control of Freeway Traffic Corridors

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Motivation

- 2007 USA Traffic Congestion Caused:
  - 4.2 billion hours of additional travel time
  - 11 billion litters of additional fuel

Congestion delay in California:
- 500,000 veh-hrs/day
- will double in 2025

San Francisco I-80 Bay-shore morning commute
What is TOPL? (Tools for Operational Planning)

TOPL provide tools to

- specify actions for traffic corridor operational improvements:
  - ramp metering, incident management, traveler information, and demand management;

- quickly estimate the benefits of such actions

TOPL is

- based on macro-simulation models that are
  - automatically calibrated using traffic data

- can be used in real time for traffic monitoring, prediction and control
The TOPL system

- GIS
  - OpenJUMP filtering
  - GIS Importer
  - Calibration of model parameters
  - Imputation of missing ramp flows
- PeMS
  - Traffic and geometric data
- Google Maps
  - manual inspection
- Scenarios
  - HOV lanes ramp metering VSL incidents special events etc.
- Preliminary Aurora XML
- Aurora Configurator
- Aurora XML
- Aurora Simulator
- Reports

network data, calibration & imputation final model simulation & analysis
San Francisco Bay Area

UC Berkeley

Stanford
Real-time speed collected by PeMS

1:00 Pm Thursday 25/6/09

I-80 East-shore freeway
I-80 East-shore Corridor

- Among the most congested corridors in the US

**I-80 Westbound Freeway**
- 23 miles (37 Km)
- 29 on-ramps and 24 off-ramps
- Loop detection at 57 locations
- HOV lane with some
  - HOV entrances/exits

**Due for major ITS corridor management improvements**
- Ramp metering, variable speed limits, etc.
I-80 East-shore Corridor

- Among the most congested corridors in the US

I-80 Westbound Freeway
- 23 miles (37 Km)
- 29 on-ramps and 24 off-ramps
- Loop detection at 57 locations
- HOV lane with some HOV entrances/exits

- Includes neighboring major arterial roads:
  - San Pablo Ave., University, etc.
Traffic Modeling and Simulation

- HOV lanes
- Ramp metering
- Manual inspection
- Scenarios
  - Ramp metering
  - VSL incidents
  - Special events etc.

- OpenJUMP filtering
- GIS Importer
- Google Maps
  - Manual inspection
- Scenarios
  - HCV lanes
  - Ramp metering
  - VSL incidents
  - Special events etc.

- PeMS traffic and geometric data
- Calibration of model parameters
- Imputation of missing ramp flows
- Preliminary Aurora XML
- Aurora Configurator
- Aurora XML
- Aurora Simulator
- Reports
Traffic systems exhibit rich and complex behavior

- Free flow VS Congestion

- Small changes in demands produce large changes in the response of the system.
- Huge amounts of historical and real-time traffic data, are required for modeling calibration and monitoring.
- Large amounts of missing, bad or noisy data.
Traffic Data Sources

- Loop detectors: occupancy, volume every 30 sec.

- Density in lane $j$: \[ \text{density}_j = \frac{\text{occupancy}_j}{g\text{-factor}_j} \]

- Lane aggregate: \[ \text{density}^{\text{agg}} = \sum_j \text{density}_j \]
Freeway On-ramp Metering Control

- Regulate rate at which vehicles enter the freeway

- May be responsive to current traffic conditions
Free-flow vs. Congestion

**Free-flow:**
- moderate density,
- high speed (60mph) (100Km/h)

**Congestion:**
- high density, low speed
  - Driver delays
  - Increased pollution
  - Inefficient use of freeway
<table>
<thead>
<tr>
<th>Microscopic Models</th>
<th>Macroscopic Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model individual vehicles</td>
<td>Model aggregate flow char. (speed, flow)</td>
</tr>
<tr>
<td>Computationally intensive</td>
<td>Computationally efficient</td>
</tr>
<tr>
<td>Time consuming/difficult to build</td>
<td>Easy to build, calibrate</td>
</tr>
<tr>
<td>Calibration difficulties</td>
<td></td>
</tr>
</tbody>
</table>
How TOPL works

Select & “prune” corridor from GIS & PeMS Files

Import corridor freeway and arterial topology into the AURORA simulator

Use PeMS traffic data for automatic
• model calibration
• imputation of missing detector data

Perform traffic operation control simulation studies and test enhancements:
• ramp metering, variable speed limits
• incident management,
• traveler information,
• demand management, etc.
How TOPL works

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- incident management,
- traveler information,
- demand management, etc.
Cell Transmission Model (CTM)
Freeway has $N$ sections (cells), $0, \ldots, N - 1$.

Each section has one on-ramp and off-ramp.

Time is discrete:

$n_i(k)$ is number of vehicles in section $i$.

$f_i(k)$ is flow in time $k$ from section $i$ to $i - 1$. 
CTM - Flow conservation **within cell**

\[ n_i(k): \text{number of vehicles in cell } i \]
\[ f_i(k): \text{flow from cell } i \text{ to cell } i - 1 \]

**Traffic Flow Direction**

\[ f_i(k) \quad \text{on–ramp flow} \quad s_i(k) \quad \text{off–ramp flow} \]
\[ n_i(k) \]
\[ f_{i+1}(k) \quad \text{on –ramp flow} \quad r_i(k) \]

Flow conservation:

\[ n_i(k+1) = n_i(k) - [f_i(k) + s_i(k)] + [f_{i+1}(k) + r_i(k)] \]
CTM - Off-ramp flow split ratios

1 mile sections, so \( n_i = \# \text{ vehicles} = \text{density} \):

\[
\text{Flow}\left(\frac{\text{veh}}{\text{hour}}\right) = \text{speed}\left(\frac{\text{mile}}{\text{hour}}\right) \times \text{density}\left(\frac{\text{veh}}{\text{mile}}\right)
\]

Off-ramp flows given by split-ratios (routing):

\[
s_i(k) = \beta_i [s_i(k) + f_i(k)] = \beta_i \bar{\beta}_i^{-1} f_i(k). \quad (\bar{\beta}_i = 1 - \beta_i)
\]
Determination of inter-cell flow

\[ f_i(k) \leq v_i n_i(k) - s_i(k) \quad \text{— demand} \]

\[ f_i(k) \leq F_i \quad \text{— capacity} \]

\[ f_i(k) \leq w_{i-1}(\bar{n}_i - n_{i-1}(k)) \quad \text{— supply} \]

\[ f_i(k) = \min\{v_i n_i(k) - s_i(k), w_{i-1}[\bar{n}_{i-1} - n_{i-1}(k)], F_i\} \]
Cell’s fundamental diagram is characterized by

- $F_i$ – capacity, max flow (vph)
- $v_i$ – free flow speed (mph)
- $w_i$ – congestion wave speed (mph)
- $\bar{n}_i$ – jam density (vpm)
- $n_i^c$ – critical density (vpm)
Typical parameter values

Per lane typical parameter values:

- $F_i = 2000 \text{ vph} = 2000 \text{ vph}$
- $v_i = 60 \text{ mph} = 100 \text{ Km/h}$
- $w_i = 20 \text{ mph} = 32 \text{ Km/h}$
- $n_i^c = 33 \text{ vpm} = 20 \text{ veh/Km}$
- $\bar{n}_i = 133 \text{ vpm} = 83 \text{ veh/Km}$
CTM Complete model

\[ f_0 \]

Traffic Flow Direction

\[ f_i(k) \]

\[ s_i(k) \quad r_i(k) \]

\[ n_i(k + 1) = n_i(k) - [f_i(k) + s_i(k)] + [f_{i+1}(k) + r_i(k)] \]

\[ f_i(k) = \min\{v[n_i(k)] - s_i(k); w[\bar{n} - n_{i-1}(k))]; F\} \]

\[ f_0(k) = \min\{v[n_0(k)] - s_0(k); F\} \]

\[ n_N(k + 1) = n_N(k) - f_N(k) + r_N(k) \]
CTM Complete model

State eq: \[ n(k + 1) = \Phi(n(k), r(k)) \]

State: \[ n(k) = (n_0(k), \ldots, n_{N-1}(k)) \]

Input: \[ r(k) = (r_0(k), \ldots, r_N(k)) \]
CTM Complete model

Traffic Flow Direction

\[ f_0 \quad 0 \quad 000 \quad f_i(k) \quad s_i(k) \quad r_i(k) \quad 000 \quad f_{N-1} \quad N-1 \quad f_N \quad r_N(k) \]

\[ n(k + 1) = \Phi(n(k), r(k)) \]

Constant demand \( r = (r_0, \cdots, r_N) \) induces unique equilibrium flow \( (f_0, \cdots, f_N) \):

\[ f_N = r_N, \]

\[ f_i = \bar{\beta}_i (f_{i+1} + r_i), \quad 0 \leq i \leq N - 1. \]
CTM Equilibrium State

\[ n(k + 1) = \Phi(n(k), r(k)) \]

\( n \) is an equilibrium state if \( n = \Phi(n, r) \).

Let \( E(r) \) be the set of equilibrium states.

**Thm** \( E(r) \neq \emptyset \), iff \( f_i \leq F_i \), all \( i \). (feasible mainline flows)
Congestion dynamics

Given a constant demand \( r = (r_0, \ldots, r_N) \) which induces a set of feasible equilibrium flows

\[
\begin{align*}
    f_N &= r_N \\
    f_i &= \beta_i (f_{i+1} + r_i), \quad 0 \leq i \leq N - 1.
\end{align*}
\]

where \( 0 \leq f_i \leq F \) and \( f_0 = F \).

The demand can produce:

- a unique equilibrium state which results in an uncongested freeway
- an equilibrium state with congested cells

Ramp metering can maintain the freeway uncongested and meet a feasible demand.
There are two stable traffic patterns:

- In this **uncongested** pattern speed is 60 mph throughout
- In this **congested** pattern speed is 26 mph throughout
Bottlenecks

Section $i$ is a bottleneck if $f_i = F_i$.

Suppose bottlenecks at $0 \leq I_1 < I_2 \cdots < I_K$.

Partition freeway into $1 + K$ segments:

$$S^0 = \{0, \ldots, I_1 - 1\}, \quad S^1 = \{I_1, \ldots, I_2 - 1\},$$
$$\ldots, \quad S^K = \{I_K, \ldots, N - 1\}.$$

Partition the state $n = (n^0, \ldots, n^K)$.
**Structure of $E(r)$**

**Thm** \( E(r) = E^0(r) \times \cdots \times E^K(r). \)

Congested sections are upstream of bottleneck.
Structure of $E(r)$

**Thm** $E(r) = E^0(r) \times \cdots \times E^K(r)$.

Congested sections are upstream of bottleneck.

I-80 West Speed Contour

*Traffic Flow Direction*

bottlenecks:
Data collection, model calibration
Gunes Dervisoglou, Gabriel Gomes
I-80 East-shore Corridor

I-80 Westbound Freeway

- 23 miles (37 Km)
- 29 on-ramps and 24 off-ramps
- Loop detection at 57 locations
- HOV lane with some HOV entrances/exits
Model calibration

Step 1: Download daily PeMS detector health data for the study section, determine good days (73 good days in Jan - Sept 2008)

Step 2: TOPL Freeway Modeler generates freeway geometry and configuration along with a loop health ranking for the good days

Step 3: Choose calibration data from the good days

Step 4: TOPL Freeway Modeler automatically calibrates the model parameters and imputes missing ramp flows

Step 5: TOPL Freeway Modeler generates configuration file for the AURORA simulation
### Freeway Geometry (I-80 E)

<table>
<thead>
<tr>
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<td>0</td>
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<tr>
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<td>4</td>
<td>1452</td>
<td>4</td>
<td>0</td>
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<td>1</td>
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<tr>
<td>4</td>
<td>4</td>
<td>5</td>
<td>1452</td>
<td>3</td>
<td>0</td>
<td>401657</td>
<td>0</td>
</tr>
</tbody>
</table>
Select good days (I-80E)

Criteria:

- Detector Health: days with over 80% health during Jan-Sept 2008

  - Moderate Congestion
    
    - ‘Normal’ operating conditions
      
      - No special events
      
      - High max. flow is indicator
Calibrating fundamental diagram

Calibration: Process of fitting a fundamental diagram to density/flow data

For each vehicle detector station estimate:
- Free flow speed $u$
- Capacity $f$
- Congestion wave speed $w$
1. Free flow speed: Least square fit of data points with speed above 55 mph.
1. Free flow speed: Least square fit of data points with speed above 55 mph.
2. Capacity: Maximum observed flow.
Data collection and model calibration

1. Free flow speed: Least square fit of data points with speed above 55 mph
2. Capacity: Maximum observed flow
3. Congestion line:
   3.1. Divide congested data into “bins”
   3.2. Take maximum non-outlier point as representative of each bin
   3.3. Fit line pivoted at the maximum flow point
Model calibration

Mainline Flow vs. Occupancy
Assign parameters to all links

Traffic Flow Direction

\[ \times \frac{2}{3} \]

links without detector
Imputating missing ramp flows
Ajith Muralidharan
Imputation of missing ramp flows

**Traffic Flow Direction**

**Motivation**

- Onramp and offramp flows are essential for simulation
- But ramps often lack a functioning detector station

**Approach**

- Use mainline measurements to infer ramp flows
- Algorithm based on adaptive learning control theory and linear programming
CTM ramp flow imputation

For all links

1. Determine link input flow $f_{i}^{in}$ and output flow $f_{i}^{out}$ to match observed density measurements $n_i$ of detector.

- Use an iterative, adaptive learning control algorithm
CTM ramp flow imputation

For all nodes

2. Determine link onramp flow $r_i$ and off-ramp flow $s_{i+1}$ to match observed flow measurements $f^M_{i+1}$ of detector.

- Solve Linear Program
Results for I-80W

- 23 miles (37 Km)
  - 29 on-ramps
  - 24 off-ramps
  - 57 loop detection stations

- All on-ramp and off-ramps flow measurements missing
Simulated versus measured velocity contours

I-80E: Feb 19, 2009 (Th)

Simulated Speeds

PeMS Measured Speeds

Traffic Flow Direction

PostMile

Time [hr]
Simulated versus measured density, flow contours

**Simulated Density**

**PeMS Measured**

Density Error = 4.18%

**Simulated Flow [veh/hr]**

**PeMS Flow [veh/hr]**

Flow Error = 7.57%
Simulated versus measured aggregate performance

VMT: Total vehicle miles travelled

VHT: Total vehicle hours travelled
I-210W Test Site

- I-210 West in Pasadena, CA (Los Angeles area - D7)
  - 26 miles long
    - 32 onramps
    - 1 uncontrolled freeway connector (I-605N)
    - 26 off-ramps
  - Heavy Congestion in commute hours
33 segment freeway - lumped into 25 mainline links with working detectors.

8 (of 32) onramps and 9 (of 26) off-ramps imputed.

Simulation using imputed ramp flows
Density Contours

Simulated Density [veh/mile]

PeMS Density [veh/mile]

Density Error = 4.92 %

Flow Contours

Simulated Flow [veh/hr]

PeMS Flow [veh/hr]

Flow Error = 8 %
Performance Measures for Freeway

Vehicle Miles Travelled

Error = 6.9%

Vehicle Hours Travelled

Error = 0.34%

Delay

Error = 6.23%
Simulating HOV lanes
Ajith Muralidharan, Alex Kurzhanskiy,
Interstate Freeways have lanes that are dedicated to HOVs during commuting times.

- Single Occupancy Vehicles (SOV) cannot transit on HOV lanes during commuting times.

HOV models have:

- Two vehicle types - HOV’s and SOV’s
- Freeway links consists of HOV and Main Line (general purpose) lanes

Two modes of operation

- HOV actuated- no SOVs in HOV lane
- HOV not actuated- HOV lane operates as general purpose lane
HOV actuation hours: 5:00 AM - 10:00 AM and 3:00 PM - 7:00 PM
I80E Simulation: **1 in 5** vehicles is HOV capable

**Mainline**

**HOV**

Path: Freeway mainline route

Path: Freeway HOV route

**Flow**

**Density**

**Speed**
I80E Simulation: **1 in 4** vehicles is HOV capable

1 in 4 has larger delay on HOV, smaller delay on ML than 1 in 5
Onramp metering
Gabriel Gomes

The TOPL System
Onramp metering algorithms

- TOPL can be used to compare onramp metering algorithms
- Algorithms currently implemented in TOPL:
  - Time of day (TOD) metering
  - ALINEA
  - SWARM 1/2a/2b (no dynamic bottlenecks yet)
- TOD and Alinea are isolated controllers, SWARM is coordinated
ALINEA ramp metering and queue override

Prof. Markos Papageorgiou

Downstream mainline detectors $n(k)$

Onramp merge detector $(r_{\text{merge}})$

Onramp meter $(r_{\text{meter}})$

Onramp queue detector

\textbf{Alinea:}

$r_{\text{meter}}(k) = r_{\text{merge}}(k - 1) + K \left( n^c - n(k) \right)$

\textbf{Queue override:} If onramp queue detector is occupied, set

$r_{\text{meter}} = r_{\text{maximum}}$
Use Google earth to estimate onramps’ queue storage capacities.
No ramp metering

Density contour

Flow contour
ALINEA with queue override

Density contour

Traffic Flow Direction

Flow contour
ALINEA without queue override

Density contour

Flow contour
No ramp metering

Total and delayed vehicles

Time

Total vehicles

- Delayed vehicles
- Non-delayed vehicles
ALINEA with queue override

Time

Total and delayed vehicles

Total vehicles

- Delayed vehicles
- Non-delayed vehicles
ALINEA without queue override

Total vehicles

Time

Total and delayed vehicles

Delayed vehicles
Non-delayed vehicles
Total vehicles hours (area under the curve)

- No control (30,869 veh.hr)
- Alinea with queue override (30,538 veh.hr)
- Alinea without queue override (30,452 veh.hr)

1.07% reduction
1.35% reduction
Total delayed vehicles

- No control (4,945 veh.hr) - 33.4% reduction
- Alinea with queue override (3,292 veh.hr)
- Alinea without queue override (2,513 veh.hr) - 49.2% reduction
Optimal Onramp metering policy
Gabriel Gomes
Optimal coordinated ramp metering

Given:

1. A calibrated CTM model (including off ramp split ratios)

2. Nominal (historic, predicted) on-ramp demands

\[ d_i(k) \quad 0 \leq k \leq K \]

3. Maximum queue lengths

\[ l_i(k) \leq L_i \]

Determine ramp flows and resulting mainline densities

\[ r_i^O(k) \quad n_i^O(k) \quad 0 \leq k \leq K \]

that minimize Total Travel Time (TTT)
The optimal ramp metering problem can be formulated as a Linear Programming Problem if

- ACTM model has time invariant split ratios
  - optimal policy metering is not hindered by mainline congestion

- Its solution gives optimal rates, queue lengths and ramp delays, and total delay
I-210 West in Pasadena, CA (Los Angeles area - D7)

- 26 miles long
  - 32 onramps
  - 1 uncontrolled freeway connector (I-605N)
  - 26 off-ramps

- Heavy Congestion in commute hours
Calibrated CTM model simulation results

Speed contour map with current ramp metering

Total Delay:

$4.2 \times 10^3$ hours
Optimal ramp metering – No queue constraints

Density Contour Plot

Total Delay reduction: 29%

unconstrained ramp queues
(including 605N interconnect)
Optimal ramp metering – With queue constraints

Density Contour Plot

Total Delay reduction: 21%

Constrained ramp queues
(including 605N interconnect)
### ACTM model - Optimal ramp metering – Performance

<table>
<thead>
<tr>
<th></th>
<th>Total Travel Time</th>
<th>Total Delay*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10^3 hours</td>
<td>10^3 hours</td>
</tr>
<tr>
<td>Current metering</td>
<td>12.2</td>
<td>4.2</td>
</tr>
<tr>
<td>No Queue Constraint</td>
<td>11.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Reduction</td>
<td>8%</td>
<td>29%</td>
</tr>
<tr>
<td>With Queue Constraint</td>
<td>11.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Reduction</td>
<td>6%</td>
<td>21%</td>
</tr>
</tbody>
</table>

* Including time spent in ramp queues

- HOV lane not modeled
Modeling arterial traffic
Andy Chow, Gabriel Gomes

The TOPL System
### Arterial vs freeway traffic

<table>
<thead>
<tr>
<th></th>
<th>Freeway</th>
<th>Arterial</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum speed</strong></td>
<td>65 mph</td>
<td>35 mph</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>2200 vphpl</td>
<td>1800 vphpl</td>
</tr>
<tr>
<td><strong>Congestion</strong></td>
<td>Bottleneck induced</td>
<td>Signal induced</td>
</tr>
<tr>
<td><strong>Network</strong></td>
<td>Simple OD patterns with single routes.</td>
<td>Complex OD patterns with multiple routes.</td>
</tr>
<tr>
<td><strong>Signals</strong></td>
<td>Single phase</td>
<td>Up to 8 phases</td>
</tr>
<tr>
<td><strong>Measurements</strong></td>
<td>Aggregate</td>
<td>Aggregate + individual actuations</td>
</tr>
<tr>
<td><strong>Algorithms</strong></td>
<td>Relatively simple (SWARM, Alinea)</td>
<td>Relatively complex (Actuated, adaptive, SCOOT, RHODES)</td>
</tr>
</tbody>
</table>
Arterial traffic

Study site: San Pablo Ave From Fairmount to Buchanan

3-link, 6-signal, 0.9-mile segment; sensors at A,B,C,D
Arterial traffic

Study site: San Pablo Ave From Fairmount to Buchanan

3-link, 6-signal, 0.9-mile segment; sensors at A,B,C,D
Arterial traffic – vehicle re-identification

Re-identify the vehicles as they go through different intersections

- New magnetometer-based wireless sensor networks
- New vehicle re-identification techniques
Re-identify the vehicles as they go through different intersections

Upstream sensor provides \(\{(s_i, X_i), i = 1, \cdots, N\}\); downstream sensor provides \(\{(t_j, Y_j), j = 1, \cdots, M\}\).

Match signatures \(X_i \rightarrow Y_j\) to get travel time \(t_j - s_i\). Note: \(X_2 \rightarrow \tau\) and \(\tau \rightarrow Y_4\).
AURORA representation of a signalized intersection

- Links and nodes
- Detector stations
- Signals

- Intersection node
- Traffic splitting node
- Entering traffic
- Through traffic
- Left-turn traffic
- Exiting traffic
Each signal has 3 possible states: GREEN, YELLOW, and RED.

Signals affect traffic by adjusting the link capacity:

\{GREEN, YELLOW\} $\Rightarrow$ Full capacity

\{RED\} $\Rightarrow$ Zero capacity
AURORA signal control algorithms model

- Signal control algorithms currently include
  - Pre-timed (multiple plans and free operation)
  - Isolated actuated
  - Coordinated actuated

- Signal control algorithms affect the signal state by issuing *hold* and *force-off* requests for particular phases
AURORA model of arterial traffic

- **DEMO**: A section of San Pablo Ave in Albany, CA
AURORA model validation

- Traffic data for May 23, 2008, 1-1:30PM, from wireless sensors installed by Sensys Networks, Inc.

- Fundamental diagram:
  - Saturation flow = 1800 vph
  - Free-flow speed = 30mph
  - Critical density = 60 vpm
  - Jam density = 200 vpm

- Current timing plan:
  - Cycle time, phase durations, offsets, and phase sequences
Travel times for San Pablo network

*Note: Simulated network assumes 0 cross traffic*
Comparison with Paramics micro-simulator

![Graph showing travel times](image-url)
Part IV Future directions
Real-time traffic state estimation

- Real-time model-based estimation

- Example:

![Diagram of Freeway State Estimator]

- Measured

- Freeway State Estimator

- Estimated

- Measured
We consider only two modes:

- pure free-flow
- full congestion
- congestion state $S_t$ is an unobserved, discrete & random finite state
Mixture Kalman Filter

V Estimation

estimated  measured  Data collected from PeMS
Congestion Mode Real-time Estimation Results

- Using density traffic data obtained from PeMS

I-210W Test Site
Congestion Mode Real-time Estimation Results

- Using density traffic data obtained from PeMS

I-210W Test Site
Model-based real time performance predictor

Model prediction: \([\rho^-_{(t_k)}, \rho^+_{(t_k)}]\)

Measurement correction: \([\rho^-_{(t_k)}, \rho^+_{(t_k)}]\)

CTM

Uncertainty Measurements

Flow

Density

Actual Measurements

Measurements + CTM

Time (minutes)

Interval Size (vpm)

Density (vpm)

5 am 11 am

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Towards a Smart Corridor TMC

- Road network
- Control center
- SCADA
- Scenario database
- Trusted, fast corridor simulator
- Traffic state estimation and prediction

Alarms:
- Recurrent congestion
- Non-recurrent congestion
- Productivity loss
- Security assessment

Supervisory Control And Data Acquisition
Real-time controller deployment

```xml
<controller class="aurora.hwc.control.ControllerA LINEA" type="0.08888" />

<limits cmin="10.0" cmax="1600.0" />

<parameter name="upstream" value="False" />
<parameter name="gain" value="60.0" />
<qcontroller class="aurora.hwc.control.Qoverride">
  <parameter name="delta" value="120.0" />
</qcontroller>
</controller>
```

2070 Controller
Summary

- Computational thinking has not yet been used to its fullest potential in the road transportation service sector whose productivity has been declining for a long time.

- The specification and calibration of nonlinear dynamical models of traffic systems require large amounts of historical and real-time traffic data, and new techniques for effectively handling this information.

- Traffic systems exhibit rich and complex behavior and require new modeling, estimation and identification techniques.

- Good traffic monitoring systems and models are needed to design good traffic control strategies.

- Communication, sensor and computational engineering advances can make this possible and cost effective.
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