Arterial data quality and traffic estimation

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Outline

- Introduction
- Cloud-based arterial performance dashboard
- Arterial traffic estimation
- Conclusion
Introduction
The I-210 Connected Corridors Pilot

- **Connected Corridors**
  - A statewide program -- [https://connected-corridors.berkeley.edu/home](https://connected-corridors.berkeley.edu/home).
  - A total entity made up of people, organization, hardware, and software.

- **The I-210 Pilot in LA**
  - Frequent freeway traffic incidents, good sensing coverage, and some unused capacity in arterials.
# A Variety of Data Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Information Type</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasadena</td>
<td>Intersection signal</td>
<td>Pasadena TMC</td>
</tr>
<tr>
<td>Duarte</td>
<td>Intersection signal</td>
<td>County TMC</td>
</tr>
<tr>
<td>Monrovia</td>
<td>Intersection signal</td>
<td>County TMC</td>
</tr>
<tr>
<td>Arcadia</td>
<td>Intersection signal</td>
<td>Arcadia TMC</td>
</tr>
<tr>
<td>LA County</td>
<td>Intersection signal</td>
<td>County TMC</td>
</tr>
<tr>
<td>Caltrans FW Traffic</td>
<td>Loop sensing</td>
<td>Caltrans ATMS</td>
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<tr>
<td>Caltrans FW Ramps</td>
<td>Ramp meters</td>
<td>Caltrans ATMS</td>
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<td>Caltrans FW CMS</td>
<td>DMS</td>
<td>Caltrans ATMS</td>
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<td>Caltrans Intersections</td>
<td>Intersection signal</td>
<td>TSMSS</td>
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<tr>
<td>Caltrans Video</td>
<td>Video</td>
<td>via RIITS</td>
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<tr>
<td>Caltrans FW Lane closure</td>
<td>Lane status</td>
<td>LCS</td>
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<tr>
<td>Caltrans incident</td>
<td>Incident</td>
<td>Caltrans ATMS</td>
</tr>
<tr>
<td>210 LCS</td>
<td>Lane status</td>
<td>High speed rail system</td>
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<td>RIITS Environmental sensing</td>
<td>Environmental</td>
<td>RIITS</td>
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<tr>
<td>RIITS Transit</td>
<td>Transit</td>
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<tr>
<td>RIITS Video</td>
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<tr>
<td>Gold line transit</td>
<td>Transit</td>
<td>NextBus</td>
</tr>
<tr>
<td>511 (Out only)</td>
<td>Response plan information</td>
<td></td>
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<tr>
<td>Bluetooth traffic</td>
<td>Travel time</td>
<td>County TMC</td>
</tr>
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</table>
Problem Statement

- Freeway data has been well studied.
- However, very limited knowledge of arterial data.
- In this presentation, we try to address the following questions:
  - How can we assess the quality of data from arterial sensors?
    - Arterial data quality analysis and arterial performance dashboard
  - How can we use the arterial data to help with traffic modeling and simulation?
    - Arterial traffic estimation
Cloud-based Arterial Performance Dashboard
Design Purpose

- An interactive tool to assess detector health and data quality.
- Help diagnose potential issues in urban sensor networks.
- Provide data support for model development.
- Is designed for flexibility and scalability.
- Will connect to the cloud-based data hub in the I-210 Connected Corridors project.
Detector Locations: An Overview
Proposed Architecture

Amazon Web Services

Front-Facing Lambda Functions
- Invoked by user’s requests

Auxiliary Lambda Functions
- Invoked when update occurs in S3

I-210 CC Data Hub

AWS S3
- Detector health
  - By detector
  - By intersection

User Web Interface

Secure connection

Local Server
- Special security connection
- Health data grind

Future deployment

Raw data

Arcadia TCS

LACO IEN

Pasadena
Proposed Performance Metrics

- **Diagnostic states**
  - No Data (Yes/No)
  - Insufficient Data (%)
  - High Values (%)
  - Zero Values (How Long / In hours)
  - Constant Values (Yes/No)
  - Inconsistent Data (%)
  - Good (Yes/No)

- **System performance**
  - Overall health rate (% of “Good” detectors for a given period)
  - Productivity (% of working days for a given period)
  - Stability (# of switches between “Good” and “Bad” for a given period)
Current User Interface: Select Tab
Current User Interface: Health Tab
Current User Interface: Result Display
Arterial Traffic Estimation
Estimation of Initial Traffic States: Problem Statement

- In order to manage corridor traffic we need to know the traffic state on the arterial.
- Estimation calculates this state using sensors.
- Estimation is done through simulation, in which the network is initially empty.
- Then, how to generate a set of “Good” traffic states at the beginning of simulation?
  - A prevailing approach: using a warm-up period
  - Issues:
    - Larger networks → Longer maximum travel times → Longer warm-up periods → More complicated network inputs & more calibration work to capture the right bottlenecks.
Estimation of Initial Traffic States: Our Solution

- **Our solution: using field observations to reconstruct traffic states**
  - **Assumption:** network traffic states are observable.
    - Get the observations $Y(t)$ at time $t$.
    - Use these observations to reconstruct the traffic states $X(t)$: i.e., $X(t) = H^{-1}(Y(t))$.

- **The fact: system observability is increasing! (More data)**
  - Good coverage of loop detectors for both freeways and major arterials
  - Penetration rate of probe vehicles is increasing
  - Real-time connection with field controllers
Our Focus: Arterial Traffic State Estimation

- Proposed architecture

Data Inputs
- Arterial Detector Data
- Arterial Signal Phasing Data
- Intersection Road Geometry

Resulting Queue Estimates

Proposed architecture

Arterial Traffic State Estimation Module
Identification of Traffic States: Key Algorithm

- Occupancy thresholds are *explicitly* calculated based on road geometry, sensor placement, signal settings, and vehicle headway.

**Advance Detector**

- Regime I: Uncongested (Free-flow)
- Regime II: Congested (Queue forms, but the downstream is free)
- Regime III: Spillback (Queue extends from the downstream)

**Stopbar Detector**

- Regime I: Uncongested
- Regime II: Congested/Spillback
Identification of Traffic States: Field Validation

Advance Detector: 608219 & Saturday Profile

Advance Detector: 608201 & Tuesday Profile

Stopbar Detector: 608202 & Tuesday Profile

Stopbar Detector: 608209 & Thursday Profile
Identification of Traffic States: Simulation Validation

- **Simulation is done using Aimsun**
  - Demand gradually increases to create congestion.
  - Downstream bottleneck is activated for a certain time period to generate queue spillback.
Validation of Queue Estimates: Proposition and Test Site

- **Proposition:** A linear relation between *Travel Time* and *Total Queue* under traffic congestion, if we assume
  - Similar intersection geometries and signal settings along an arterial.
  - Two vehicle states (Herman and Prigogine, 1979): either stopped or moving at speed $v_0$.
  - Traffic delay calculated by the HCM method (HCM, 2000).

- **Test Site**
Validation of Queue Estimates: Results

Eastbound

Westbound
Initial Traffic States in Aimsun: Algorithms

- **Generating simulated vehicles**
  - Conversion: from average queue to both queued and moving vehicles
    - Adjusted using signal settings from the field
  - Vehicle generation: vehicles with attributes of lane ID, turning movement, and OD information
    - Based on the Aimsun network and simulation backup
- **Vehicle assignment**
  - Criteria (for each turning movement)
    - Queued vehicles first, and moving vehicles next
    - Vehicle assignment from downstream to upstream
    - When dedicated lanes are full, vehicles are assigned to the adjacent lanes
- **Overwriting active signal phases according to field signal settings**
Initial Traffic States in Aimsun: Application

The I-210 Connected Corridors Network

Vehicles generated from field detectors
Conclusion
Arterial Data Quality and Traffic Estimation

- **The cloud-based arterial performance dashboard**
  - Is designed for flexibility and scalability.
  - Can be used to evaluate the data quality and monitor the performance of sensor networks.
  - More features will be added in the near future.

- **Arterial traffic state estimation**
  - Has been validated using observations from the field and simulation.
  - Is being applied to the I-210 Connected Corridor Pilot.
  - Will be improved by incorporating probe data in the near future.

- **If you are interested in knowing more about the I-210 Connected Corridors Project, please contact:**
  - PI: Prof. Alex Bayen ([bayen@berkeley.edu](mailto:bayen@berkeley.edu))
  - Program Manager: Joe Butler ([joebutler@path.berkeley.edu](mailto:joebutler@path.berkeley.edu))
Thank you!