Statewide Truck Freight Activity using Enhanced Traffic Sensor Systems

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Trivia #1

Which of the following corridors has seen the highest volume of double belly dump trailer trucks in 2017?

- I-5 at Stockton
- US-101 at Paso Robles
- SR-99 at Fresno
- SR-14 at Santa Clarita
- I-5 at South OC / San Clemente
Trivia #1

Which of the following corridors has seen the highest volume of double belly dump trailer trucks in 2017?
Trivia #2

What is the approximate daily weekday volume of logging trucks traveling westbound on the I-80 in the San Francisco East Bay in Sep 2017?

a. 30
b. 50
c. 100
d. 200
Trivia #2

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Existing Truck Activity Data Sources

**Mobile**
- GPS
- Telematics

**Static / Count Data**
- Weigh-In-Motion (WIM)
- Automatic Vehicle Classifier (AVC) System

**Surveys**
- 2002 National Vehicle Inventory and Use Survey (VIUS)
- 2016/17 California VIUS
- Regional Intercept Surveys
The Research Question

Can we leverage existing infrastructure to provide detailed truck activity data at the statewide level to meet freight data and modeling needs?

Our Solution

Develop comprehensive cutting-edge classification models that
– can be implemented at existing traffic detector sites
– to provide truck activity data by industry-affiliated (and to some degree freight-specific) configuration
– by enhancing already invested detector technologies
Loops are out there!
Common In-Pavement Detection Systems:

- Standalone Inductive Loop Detector System
- Automatic Vehicle Classifier (AVC) System with Piezo Sensors
- Weigh-In-Motion (WIM) System
Inductive Signature Technology

• Conventional ILD measure bivalent outputs
  – Produce traffic counts, not truck counts
• Advanced ILD measure inductance changes → ‘Inductive Signature’
  – Inductive signatures are indicative of body configuration

Conventional Measurement
[0,1] Binary output

Inductive Signature
Inductive magnitude changes at up to 1200 samples/sec
How Distinctive Are Inductive Signatures?

Sample FHWA Class 9 (5- Axle Semi-Trailer) signatures by trailer configuration
Data Collection and Processing Effort for Model Development and Validation

- 18 sites across California spanning multiple geographical regions
- Over 140 hours of data with more than 40,000 truck records captured and processed

Vehicle axle and body configuration entries, and inductive signature and WIM data are manually linked in a database through a custom groundtruth interface.
Body Classification Model Architecture

**Inductive Signature Model**

Diagram showing the classification model architecture with tiers and classes:

- **Tier 1**
  - Single-Units
  - Multi-Units

- **Tier 2**
  - Passenger Vehicle
  - Single Unit w/ Trailer
  - Multi Unit w/ Single Trailer

- **Tier 3**
  - 4 Classes
  - 6 Classes
  - 8 Classes

Inductive Signature Data graph is also shown.
# Selected Body Classification Model Results

## Tier 3 Multi-Unit Single Trailer Results by Body Type

<table>
<thead>
<tr>
<th>Body Type</th>
<th>Training CCR</th>
<th>Training Samples</th>
<th>Common Site Validation CCR</th>
<th>Common Site Validation Samples</th>
<th>Independent Site Validation CCR</th>
<th>Independent Site Validation Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosed Van Group</td>
<td>97%</td>
<td>8762</td>
<td>95%</td>
<td>3548</td>
<td>92%</td>
<td>950</td>
</tr>
<tr>
<td>Tank/Dump</td>
<td>78%</td>
<td>780</td>
<td>64%</td>
<td>340</td>
<td>77%</td>
<td>130</td>
</tr>
<tr>
<td>Platform Group</td>
<td>84%</td>
<td>2071</td>
<td>77%</td>
<td>835</td>
<td>75%</td>
<td>197</td>
</tr>
<tr>
<td>40ft Container</td>
<td>79%</td>
<td>536</td>
<td>80%</td>
<td>247</td>
<td>84%</td>
<td>123</td>
</tr>
<tr>
<td>20ft Container</td>
<td>77%</td>
<td>124</td>
<td>68%</td>
<td>50</td>
<td>44%</td>
<td>43</td>
</tr>
<tr>
<td>Auto</td>
<td>94%</td>
<td>93</td>
<td>75%</td>
<td>40</td>
<td>54%</td>
<td>13</td>
</tr>
<tr>
<td>Livestock</td>
<td>97%</td>
<td>74</td>
<td>83%</td>
<td>30</td>
<td>80%</td>
<td>5</td>
</tr>
<tr>
<td>Logging</td>
<td>91%</td>
<td>81</td>
<td>100%</td>
<td>12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Overall CCR</strong></td>
<td><strong>93%</strong></td>
<td><strong>12521</strong></td>
<td><strong>89%</strong></td>
<td><strong>5102</strong></td>
<td><strong>85%</strong></td>
<td><strong>1468</strong></td>
</tr>
</tbody>
</table>

**CCR:** Correct Classification Rate

- Enclosed van
- Open top van
- Agriculture
- 53ft Container
- Platform
- Container Chassis
- Low boy platform
- Drop frame van
Signature Implementation at ILD Sites

- Upgrading hardware at ILD sites is straightforward
  - Simple swapping of advanced detector cards in roadside traffic cabinet
  - Installation of field processing unit and configure detector cards
  - No need for in-pavement installation requiring traffic closures
  - Existing traffic operations are not compromised

Conventional Detector Cards

Solid-State Field Processing Unit

- Independent wireless communications
- Receives and processes signature data from detector cards via USB

Advanced Signature Detector Cards

Before

After

Hardware setup at I-15 freeway in Fallbrook
Total Currently Deployed Sites

90+ sites deployed across all 12 Caltrans districts
- 70+ Inductive Loop Sites
- 20+ Weigh-In-Motion Sites

Coverage:
- California Gateways
- Inter-Regional Cordons
- Key Metropolitan Corridors

Legend
- Inductive loop sites
- WIM sites

UCI ITS

REDIS Middleware
- Channel 1
- Channel 2
- Channel 3
- Channel n

SSH Tunnel

Database Bridge

PostgreSQL Database
The Outcome: **Truck Activity Monitoring System (TAMS)**

http://freight.its.uci.edu/tams

*A truck counting system that is...*

- **Temporally Continuous**
  - Vehicle-level data transmitted and archived real-time 24/7

- **Spatially Representative**
  - Deployed at over 90 major truck corridors across California

- **Sustainable**
  - Leverages existing Inductive Loop and Weigh-In-Motion Detector infrastructure

- **Advanced**
  - Adopts Inductive Loop Signature technology (combined with Weigh-In-Motion technology where available)

- **High Fidelity**
  - Identifies over 40 truck / trailer body configurations

- **Accessible and Automated**
  - Hosted on an interactive GIS-enabled web-based user interface
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- **Advanced** – Adopts Inductive Loop Signature technology (combined with Weigh-In-Motion technology where available)
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Daily Average Truck Volumes Analysis

Eastbound I-80 near Pinole (Weekday)

Eastbound I-80 near Pinole (Weekend)

Southbound US-101 near Palo Alto (Weekday)

Northbound I-5 n/o Stockton (Weekday)

SF Bay

Sacramento

Stockton

Int'l Containers (20' & 40')

Domestic Containers (53')

Enclosed Vans

Eastbound I-580 in Castro Valley (Weekday)
## Anonymous Truck Tracking

**Legend**
- Detection sites
- Major intersections

- **Down** Camp Pendleton (I5)
- **Up 1** Tri-City (SR 78)
- **Up 2** Carlsbad (I5)

- Approx. 5 miles
- Data collection on July, 2016
- 67% of vehicles passed both up- and downstream locations

### Tracking Accuracy

<table>
<thead>
<tr>
<th></th>
<th>All trucks (424 veh)</th>
<th>Multi Unit (245 veh)</th>
<th>Single Unit (179 veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tracking Accuracy</strong></td>
<td>81%</td>
<td>90%</td>
<td>61%</td>
</tr>
</tbody>
</table>

### Dataset

<table>
<thead>
<tr>
<th>Dataset</th>
<th># of Trucks at Downstream</th>
<th># of Trucks at Upstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-Up1</td>
<td>424</td>
<td>421</td>
</tr>
<tr>
<td>D-Up2</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>539</td>
<td></td>
</tr>
</tbody>
</table>
Estimate proportions of freight and non-freight truck movements

Analysis of empty movements in freight trucks

Applications

Determine temporal and spatial travel patterns of trucks by industry

Estimate proportions of long and short haul trips along major and restricted truck corridors
Just Getting Started: *A platform for future research and applications*

- Analysis of archived raw signature data
- Identify alternative energy trucks?
- Profile overloaded trucks?
- Improved tracking through integration with other technologies and datasources such as Bluetooth / GPS
1.  Walk Through TAMS Web Interface (http://freight.its.uci.edu/tams)
2.  Live Classification Demo