Using High-Resolution Detector and Signal Data to Support Crash Identification and Reconstruction

Indrajit Chatterjee

Gary Davis

May, 2011
Introduction

• Road accidents are complex phenomenon.
  Causal factors such as excessive speed, successive braking of vehicles, signal violation, inadequate gap acceptance.

• Causality via Measurability.
  Can the existing traffic performance measure system help us to learn about driver behaviors involved in an event?
“More Data, Precise the Estimate”

• Classical skid mark problem in crash reconstruction.

\[ v = \sqrt{2 \times \mu \times g \times d}, \]

• Assumption: Prior knowledge about \( \mu \) (say, uniform).
• Measurement: skid mark, d with some measurement error (say, normal error).
• Using Bayesian approach, posterior distribution of pre-skid speed.
• Now, assume we have some occupancy data from near-by detector.
Posterior Speed Distribution

Density

Posterior Speed in feet/sec

- No detector info
- With detector info
High-Resolution Data

• Evaluate arterial performance measures such as travel time, queue length estimation and travel delay.

• **SMART-SIGNAL** is one such integrated event based data collection and storage system (Dr. Henry Liu, UMN).

• Collects including every vehicle actuation over detectors located near intersections and every signal phase change. - individual vehicle arrival and departure time and signal phase change.
### Sample SMART Signal data

<table>
<thead>
<tr>
<th>Detector</th>
<th>Actuation start</th>
<th>occ (secs)</th>
<th>Phase</th>
<th>Signal start</th>
<th>status</th>
<th>dur (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>10:30:33.515</td>
<td>2.578</td>
<td>6</td>
<td>10:30:30.328</td>
<td>G</td>
<td>59.203</td>
</tr>
<tr>
<td>26</td>
<td>10:30:37.125</td>
<td>1.218</td>
<td>6</td>
<td>10:31:29.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:30:39.281</td>
<td>0.969</td>
<td>6</td>
<td>10:32:23.828</td>
<td>G</td>
<td>55.703</td>
</tr>
<tr>
<td>26</td>
<td>10:30:42.921</td>
<td>0.813</td>
<td>6</td>
<td>10:33:19.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:30:45.359</td>
<td>0.859</td>
<td>6</td>
<td>10:33:59.640</td>
<td>G</td>
<td>73.891</td>
</tr>
<tr>
<td>26</td>
<td>10:30:46.750</td>
<td>0.734</td>
<td>6</td>
<td>10:35:13.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:31:01.156</td>
<td>0.422</td>
<td>6</td>
<td>10:36:25.031</td>
<td>G</td>
<td>72.5</td>
</tr>
<tr>
<td>26</td>
<td>10:31:02.859</td>
<td>0.375</td>
<td>6</td>
<td>10:37:37.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:31:19.109</td>
<td>0.344</td>
<td>6</td>
<td>10:38:54.343</td>
<td>G</td>
<td>47.203</td>
</tr>
</tbody>
</table>
Case Study of Signal Violation
Identification Methodology

- Source of data
  - Preliminary Crash Report. (crash occurred around 16:07)
  - Detector and signal data from SMART-SIGNAL system. (for a time window bracketing the crash occurrence)

- Segregate the detector actuation events (i.e. occupancy time) based on whether the corresponding signal phase was red or green.
  - Occupancy plots corresponding to separate green and red phases for detectors 4 and 3 (EB TH 55, 400 feet u/s)
Signal Layout

Note: Figure created by Dr. Liu, and his students
Occupancy pattern for detector 4 (red phase)
Occupancy data for detector 4 during red phase

Mean occupancy = 0.467 secs

(16:06:42.718, 0.235 secs)
Post-Incident occupancy pattern at detector 4 during green phase
Post-Incident occupancy pattern at detector 3 green phase
Parameter Change Technique

- Page(1954) introduced CUSUM statistic to detect change in the mean value.
- CUSUM is based on prior knowledge of the expected measure of a process.

Suppose a sequence, \( \{t_1, t_2, \ldots, t_n\} \), such that

\[
t_i = \mu + \varepsilon_i \quad \forall \ i = 1, \ldots, n
\]

\[
CUSUM, \ CS_i = \sum_{i=1}^{n} (t_i - \mu)
\]
CUSUM Example

- A sequence of two Gaussian/Normal processes

\[ t_i \sim N(0, 0.20) \quad \forall \ i < 150 \]

\[ t_i \sim N(0.15, 0.20) \quad \forall \ 150 \leq i \leq 300 \]
CUSUM statistic for occupancy at detector 3

**A change in the occupancy trend after 16:06:27.078 is identified.**
Identification of Unit 2 (SB on Winnetka Ave)

- Crash report indicated that unit 2 was a 2002 Buick LeSabre.

\[ d' = 123.86 \text{ feet} \]
Unit 2 identification

• A very high occupancy time for detector 8 was recorded at 16:06:52.906.

• Based on CUSUM statistics we have a bound for time of crash 16:06:27.078 and 16:06:52.906.

• Unit 2 was then identified as the most probable vehicle recorded at detector 7 or 8 with an estimated speed, based on the occupancy time, to arrive at the collision point within the bound.

(Unit 2 was the vehicle recorded at detector 7 at 16:06:45.937 with occupancy time of 1.438 secs.)
Crash Reconstruction

- Baker’s (1990) notion of causal factors – “circumstances contributing to a result without which the result could not have occurred.”

- Given the initial speed estimates and locations (both space and time) from detector data, what could be learned about the behavior of the drivers involved in the crash.

- Trajectories of the two approaching vehicles (assuming constant speed) were modeled by numerically solving a system of difference equations.
Separation Distance Based on Initial Speed Estimates

**Note:** Given the initial speed estimates, Unit 1 would have arrived earlier than Unit 2 at the potential conflict point.
Traditional accident reconstruction

• Accident reconstruction involves estimation of the speed of the vehicles at the point of collision from post collision information.

• Given such post collision information, it is possible to estimate driver behaviors contributing to the crash.

• In the absence of such detailed information a plausible hypothetical post collision scenario was added for illustration.
Post-collision scenario

Approximately 60 feet

5 to 20 feet

Approximately 60 feet
• Applying impulse-momentum principle, collision set was established as

\[ \{(d, v_1, v_2) : d < d_{crit}, 16245 < v_1 < 240 \text{ and } 267 < v_2 < 390 \} \],

where, \( d_{crit} \) (14.7 feet) is the crash closeness threshold.

• Simulation model

  3 parameter model is selected.

  (a) Unit 2 acceleration (\( acc2 \) in feet/sec\(^2 \))

  (b) Unit 1 deceleration (\( dcc1 \) in feet/sec\(^2 \))

  (c) For unit 1, driver perception-reaction time (\( rt \) in secs)

• Monte Carlo Simulation
The point estimate of the collision time from the simulation was found to be 16:06:50.481, which is within the bound suggested by CUSUM statistics.
Conclusion

• Demonstrate SMART-signal data along with crash report can be used to learn about an event.

• Parameter change (CUSUM) used to identify the crash based on occupancy measurements, however, this methodology may not yield good results for all cases, particularly for less severe incidents.

• If specific details regarding post-collision status of the vehicles, (e.g. in case of fatal crashes) are available successful reconstruction of the event is possible.
THANK YOU!