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

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Driven to Discover℠

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?

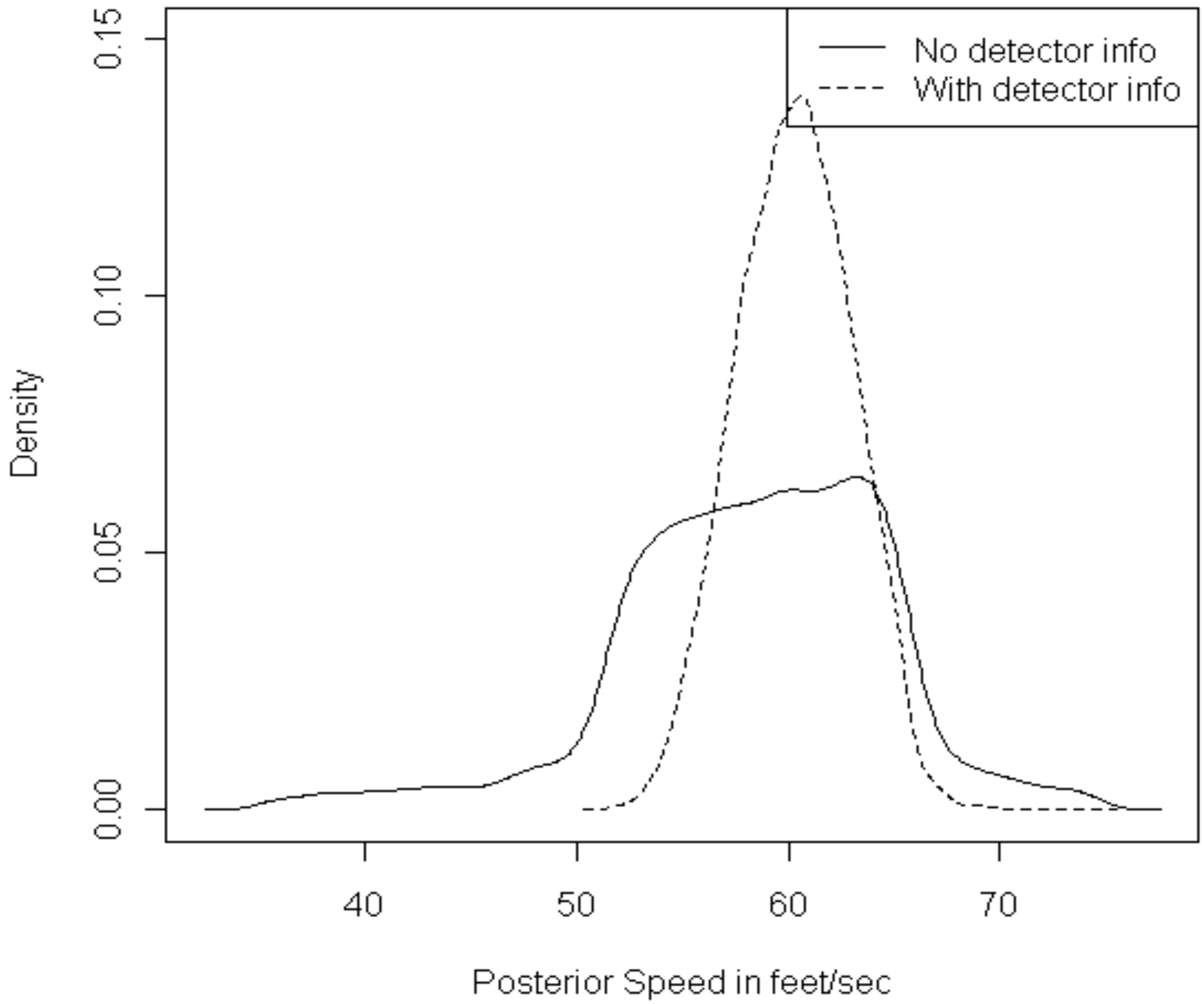
"More Data, Precise the Estimate"

- Classical skid mark problem in crash reconstruction.

$$\boldsymbol{v} = \sqrt{2 \times \mu \times \boldsymbol{g} \times \boldsymbol{d}},$$

- Assumption: Prior knowledge about μ (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



High-Resolution Data

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

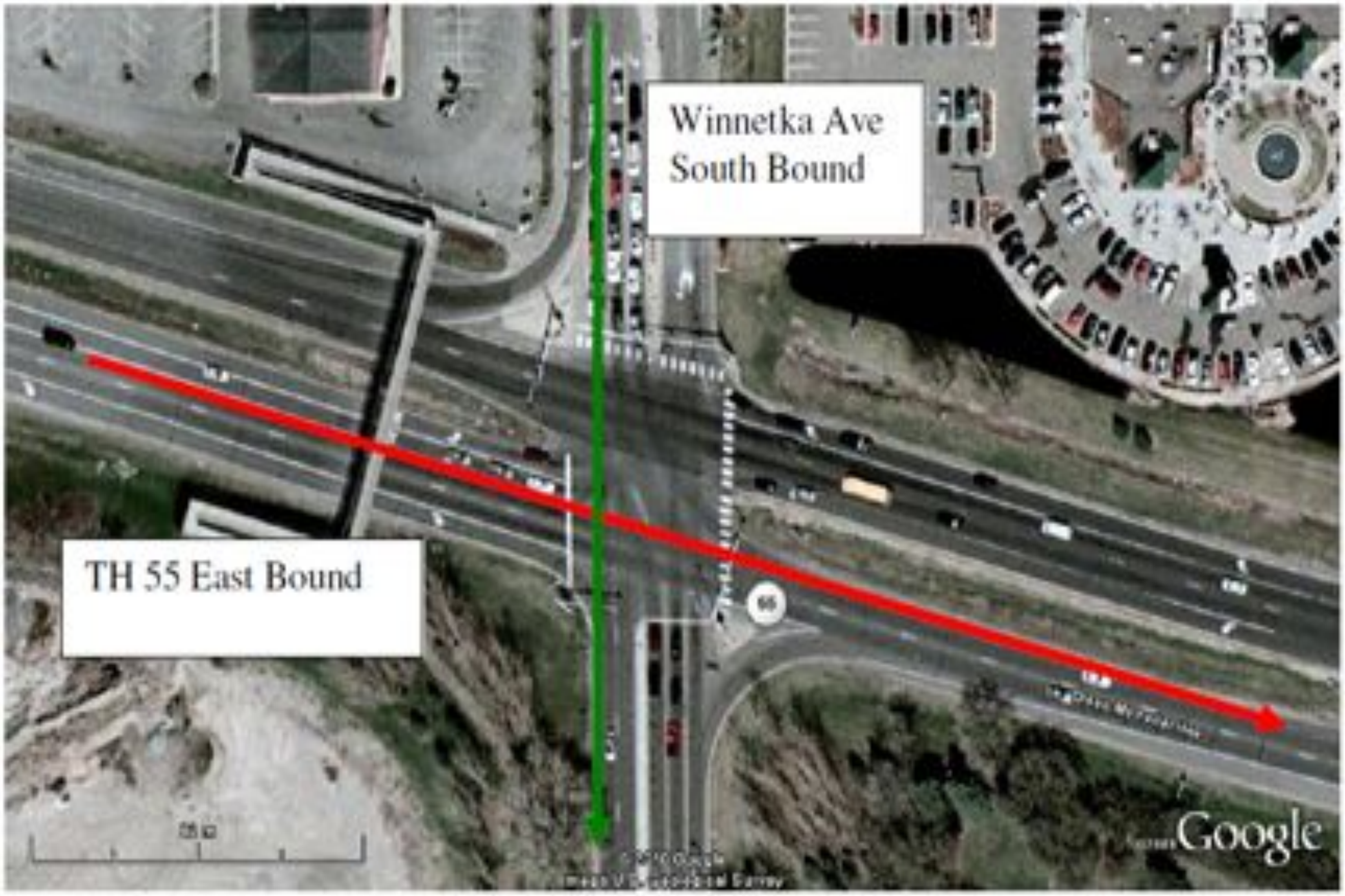
- **SMART-SIGNAL** is one such integrated event based data collection and storage system (Dr. Henry Liu, UMN).

- 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

Detector	Actuation start	occ (secs)	Phase	Signal start	status	dur (secs)
26	10:30:33.515	2.578	6	10:30:30.328	G	59.203
26	10:30:37.125	1.218	6	10:31:29.531	Y	5.5
26	10:30:39.281	0.969	6	10:32:23.828	G	55.703
26	10:30:42.921	0.813	6	10:33:19.531	Y	5.5
26	10:30:45.359	0.859	6	10:33:59.640	G	73.891
26	10:30:46.750	0.734	6	10:35:13.531	Y	5.5
26	10:31:01.156	0.422	6	10:36:25.031	G	72.5
26	10:31:02.859	0.375	6	10:37:37.531	Y	5.5
26	10:31:19.109	0.344	6	10:38:54.343	G	47.203
26	10:31:24.562	0.406	6	10:39:41.546	Y	5.485

Case Study of Signal Violation



Identification Methodology

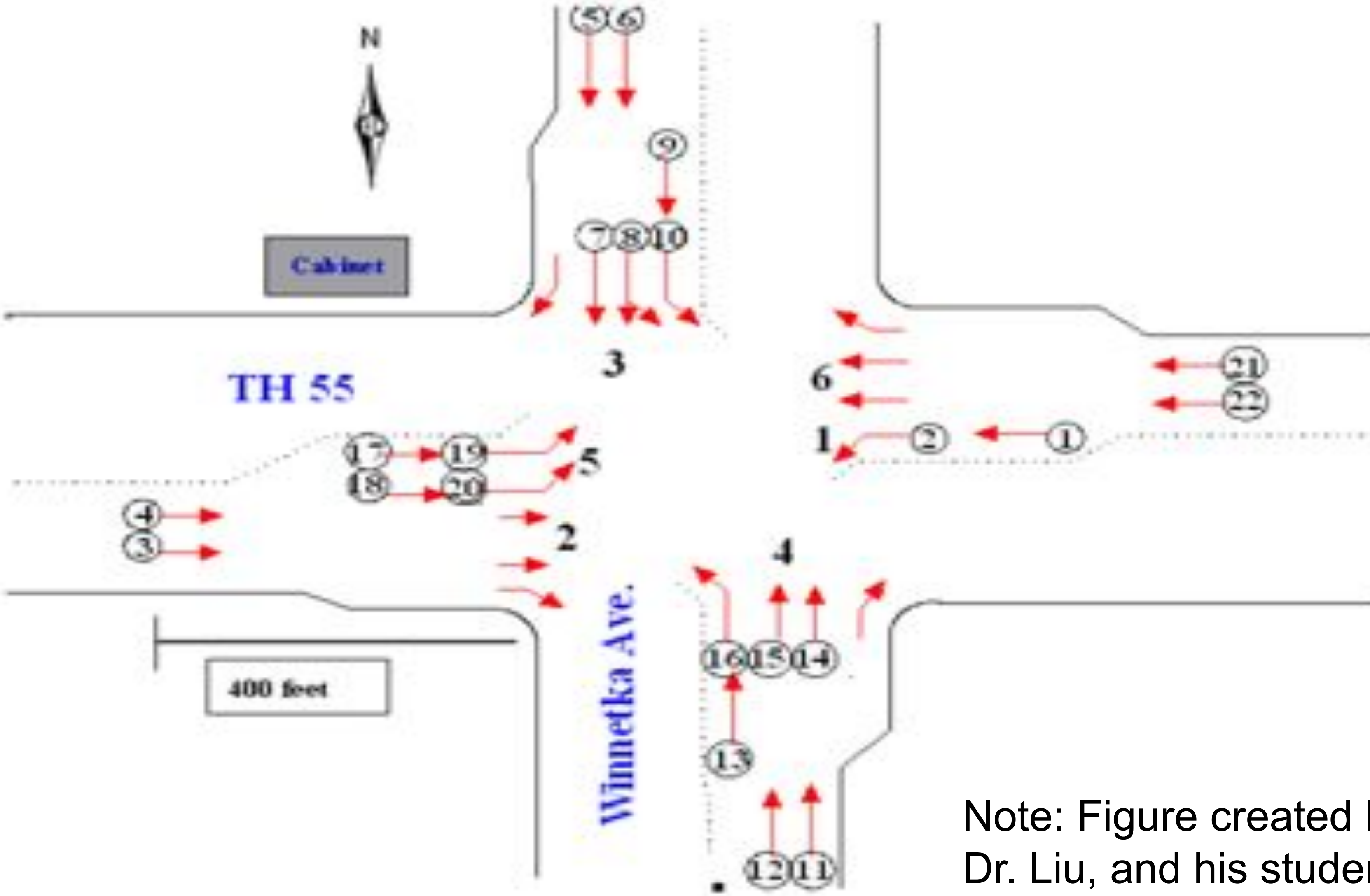
- Source of data

- 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.

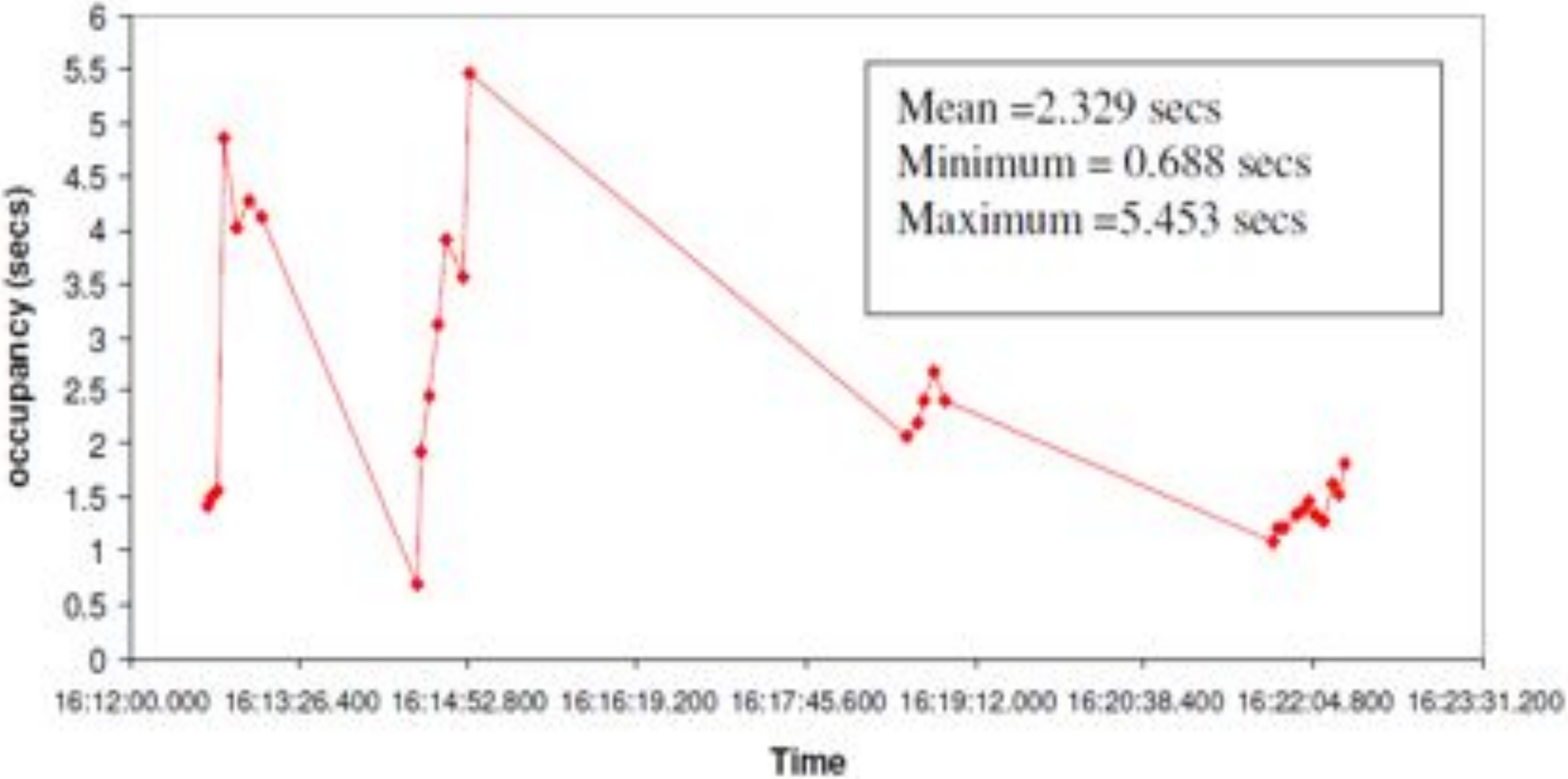
- Occupancy plots corresponding to separate green and red phases for detectors 4 and 3(EB TH 55, 400 feet u/s)

Signal Layout

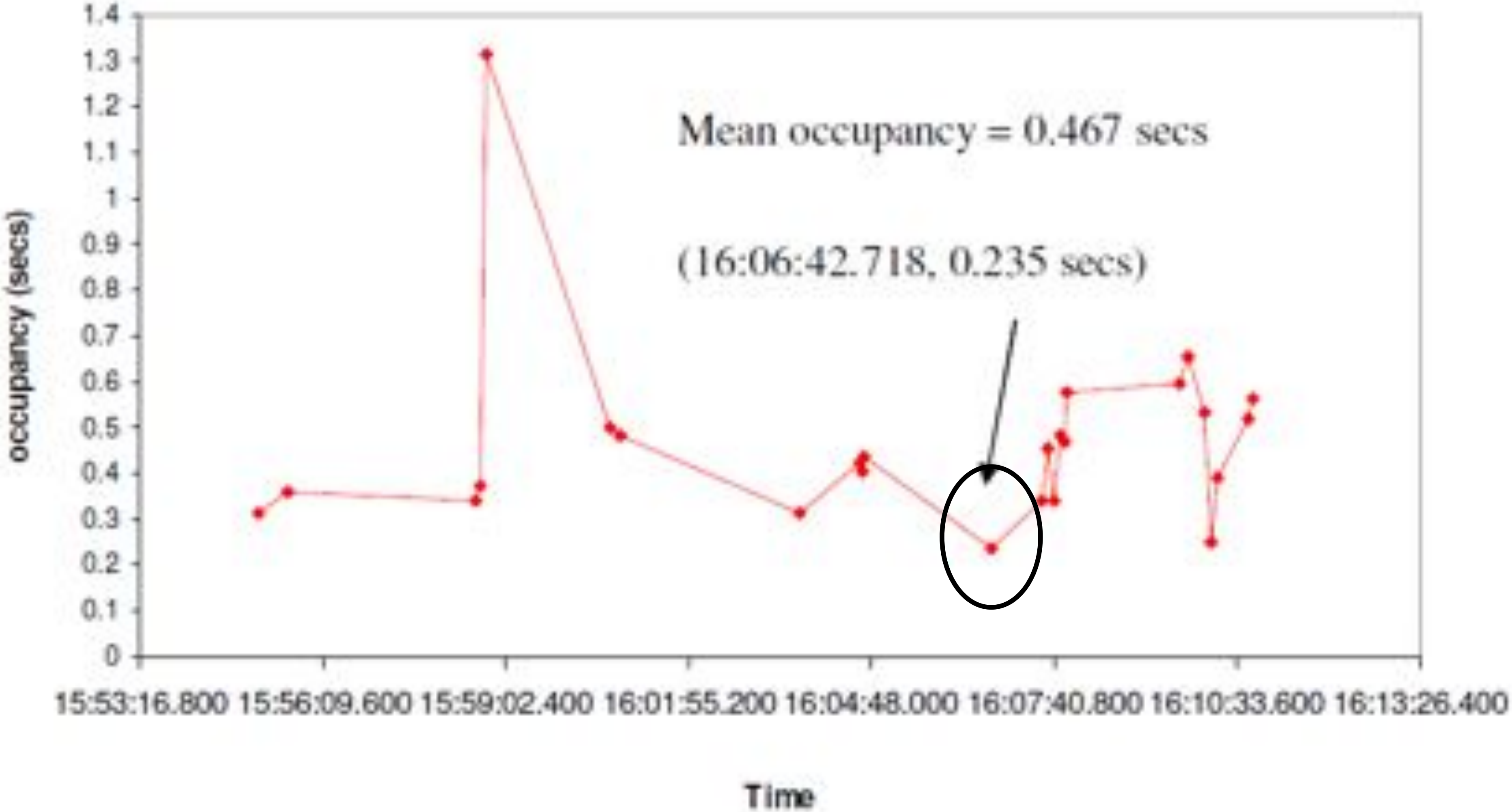


Note: Figure created by Dr. Liu, and his students

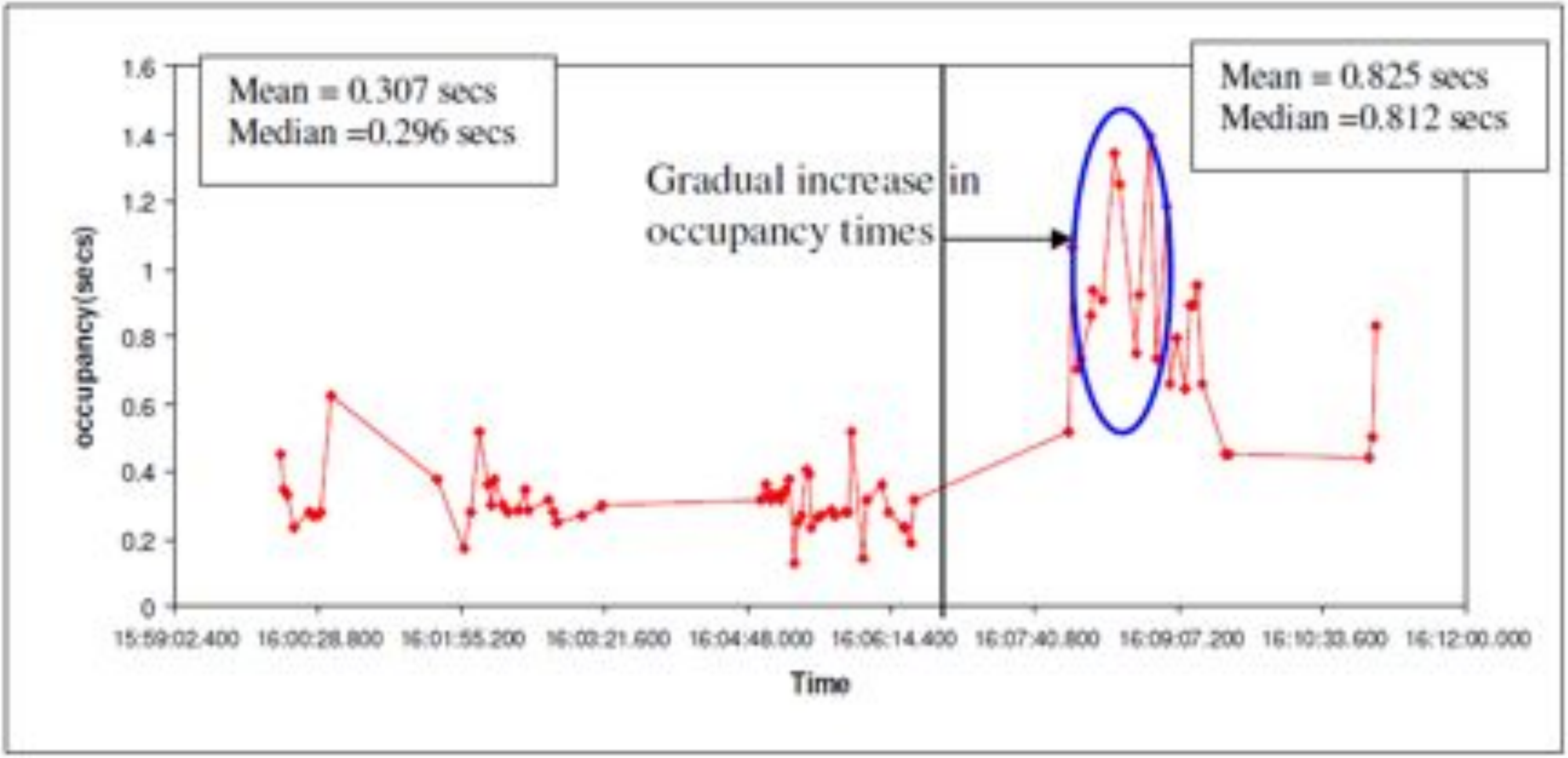
Occupancy pattern for detector 4 (red phase)



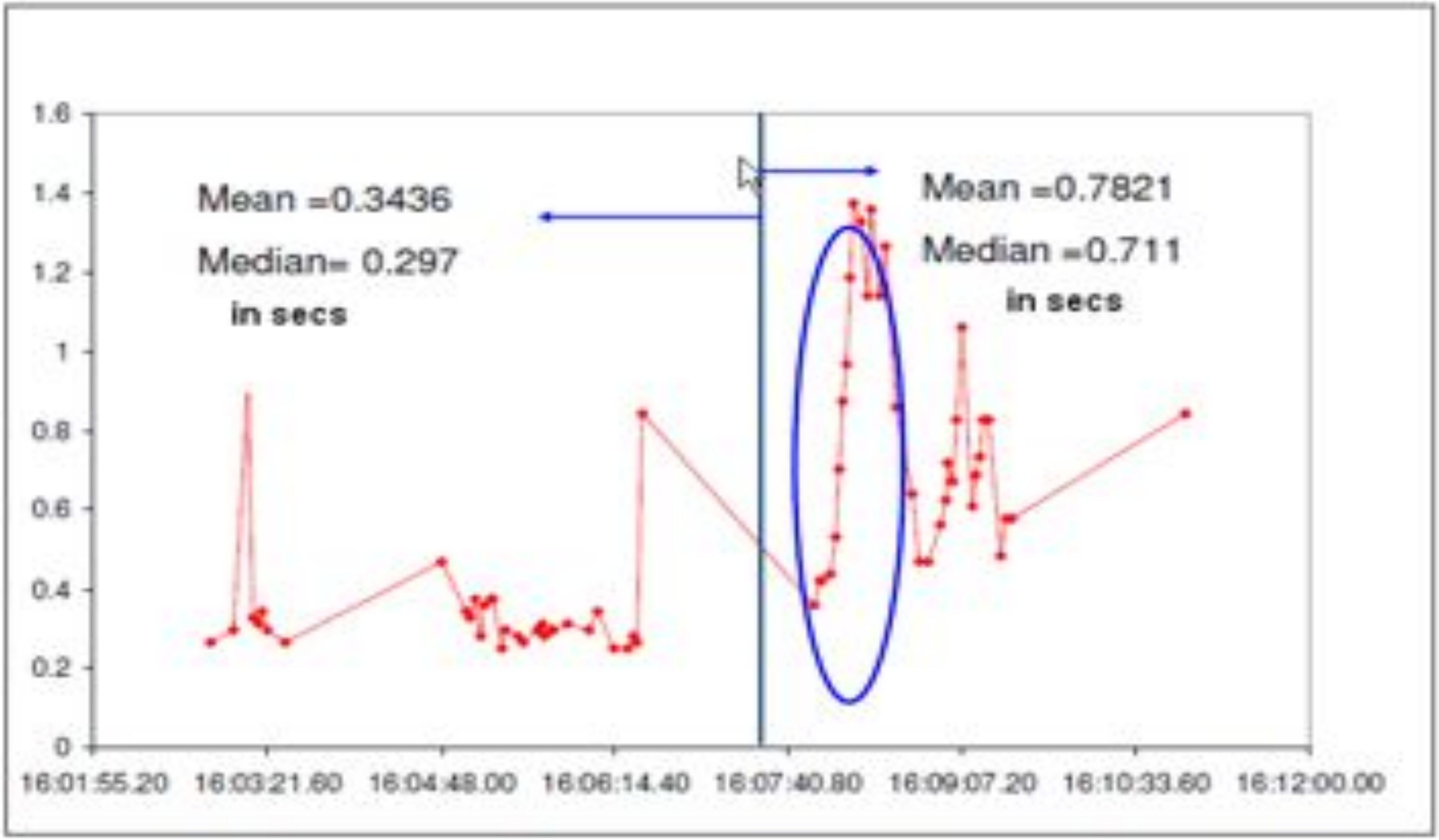
Occupancy data for detector 4 during red phase



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

$$t_i = \mu + \varepsilon_i \quad \forall\, i = 1 \ldots\ldots. n$$

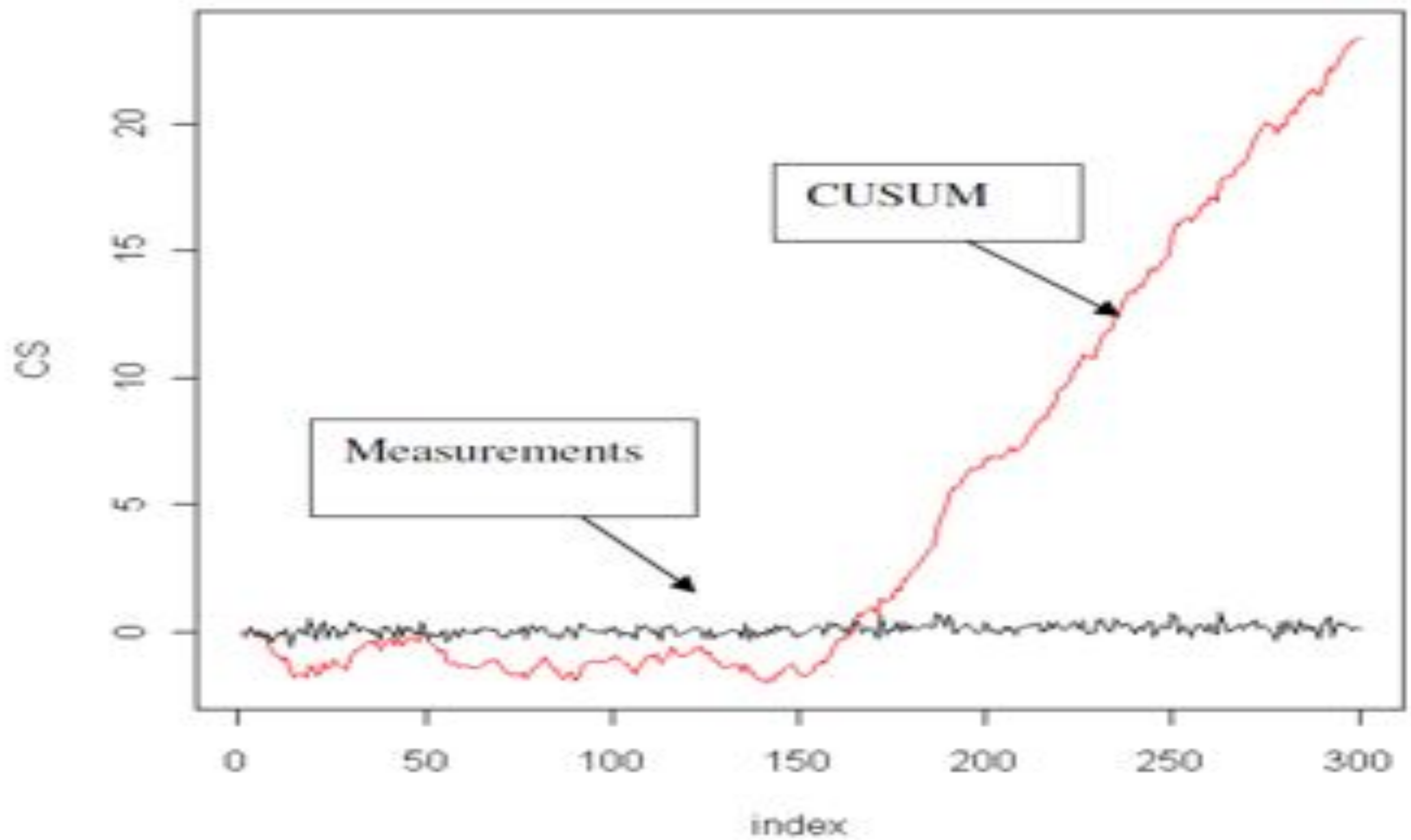
$$CUSUM, CS_i = \sum_{i=1}^{n} (t_i - \mu)$$

CUSUM Example

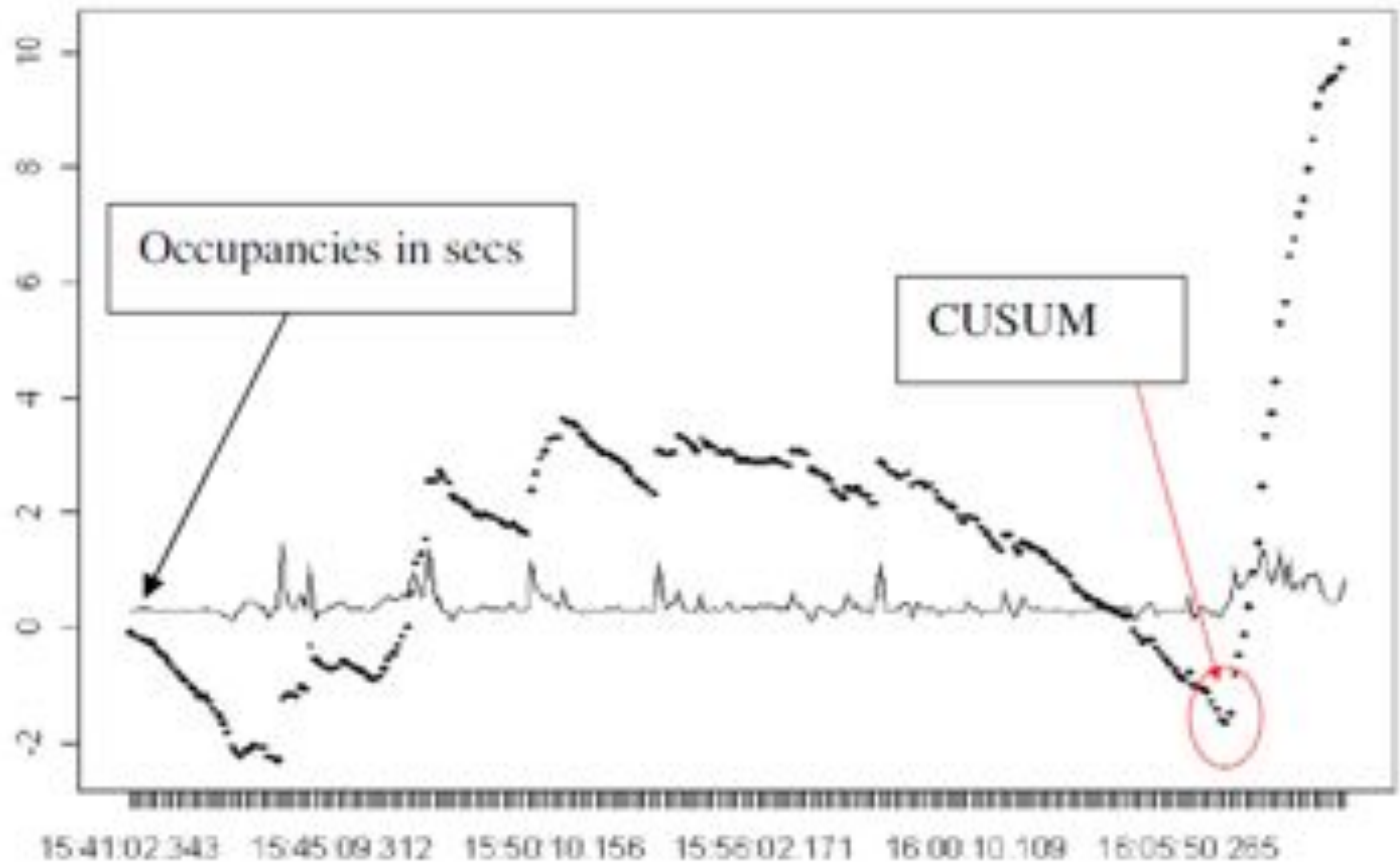
- A sequence of two Gaussian/Normal processes

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

$$t_i \sim N(0.15,0.20) \quad \forall\, 150 \le i \le 300$$



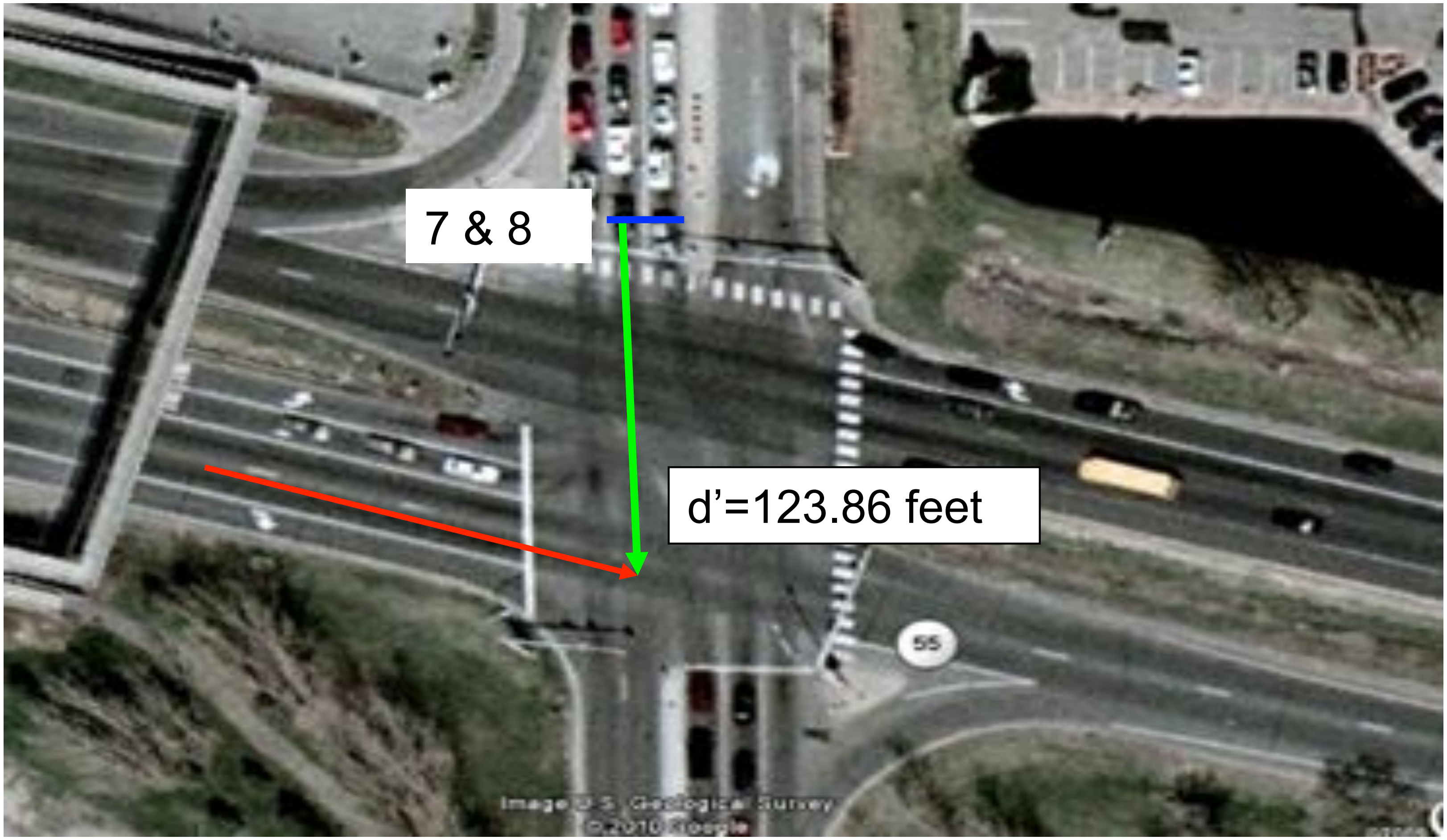
CUSUM statistic for occupancy at detector 3



**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.



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.)

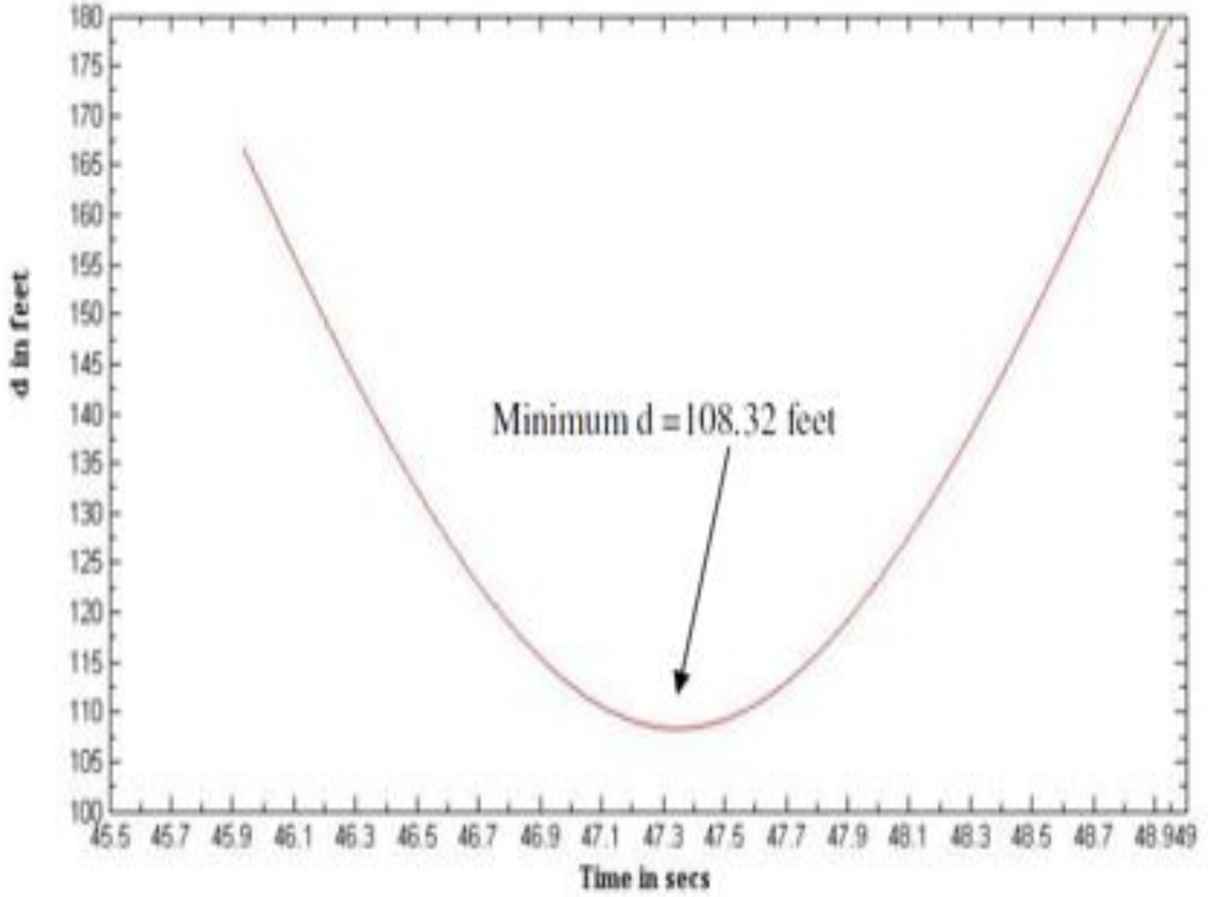
Crash Reconstruction

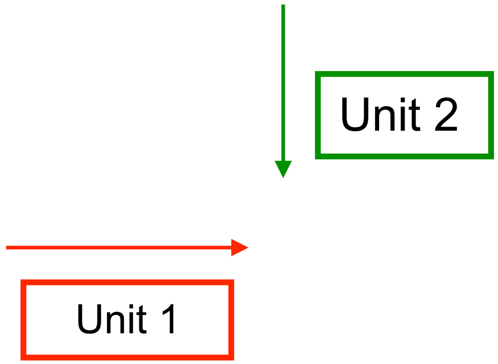
- Baker's(1990) notion of causal factors – "circumstances contributing to a result without which the result could not have occurred."

- 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



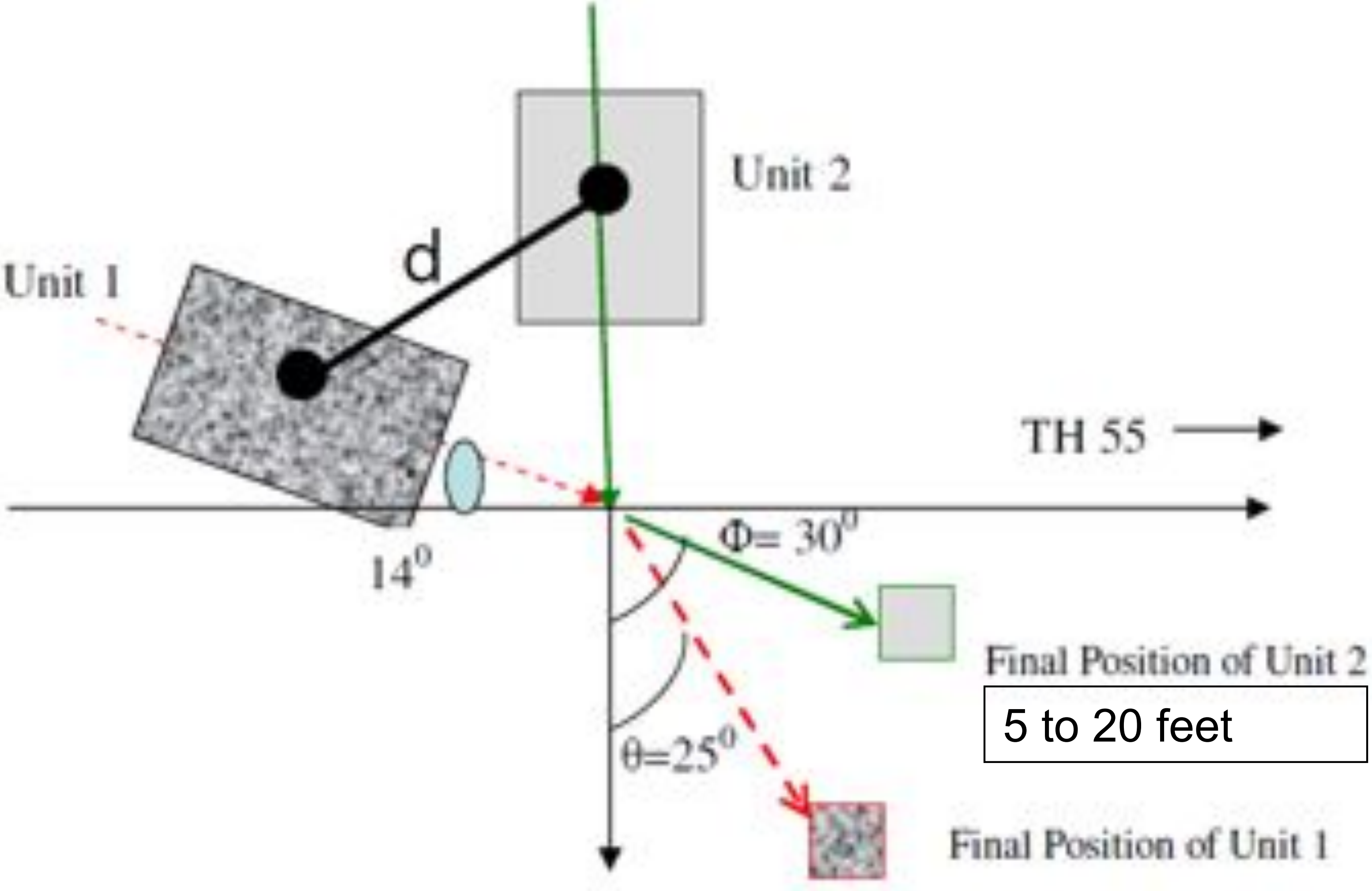


Note: Given the initial speed estimates, Unit 1 would have arrived earlier than Unit 2 at the potential conflict point.

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



5 to 20 feet

Approximately 60 feet

- Applying impulse-momentum principle, collision set was established as

$$\{(d, v_1, v_2): d < d_{crit}, 16.245 < v_1 < 24.0 \text{ and } 26.7 < v_2 < 39.10\},$$

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

TABLE 1 Sample Statistics from Monte Carlo Simulation

Parameters	Mean	Standard deviation
acc2(feet/sec^2)	4.65	0.529
dcc1(feet/sec^2)	-10.157	0.632
rt (secs)	0.337	0.251

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!