

The Pothole Patrol

6.S062 Spring 2018
Lecture 8
3/6/2018

Balakrishnan & Adib

Based on Slides from Jakob Eriksson

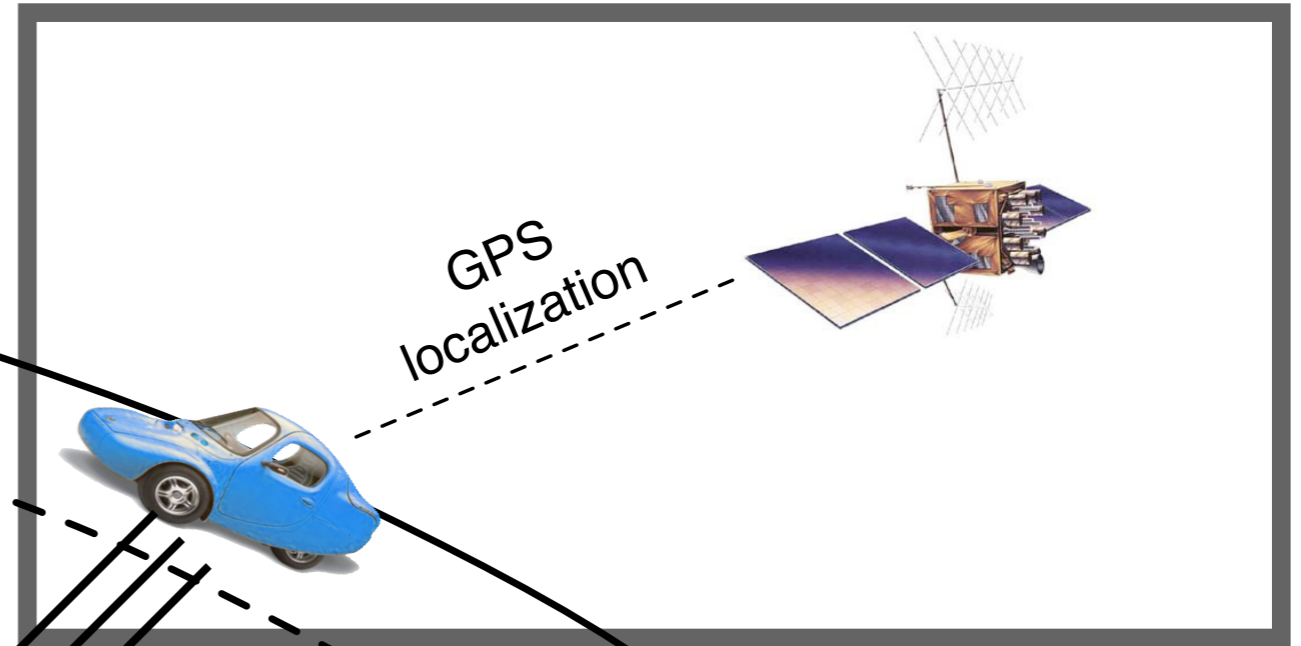
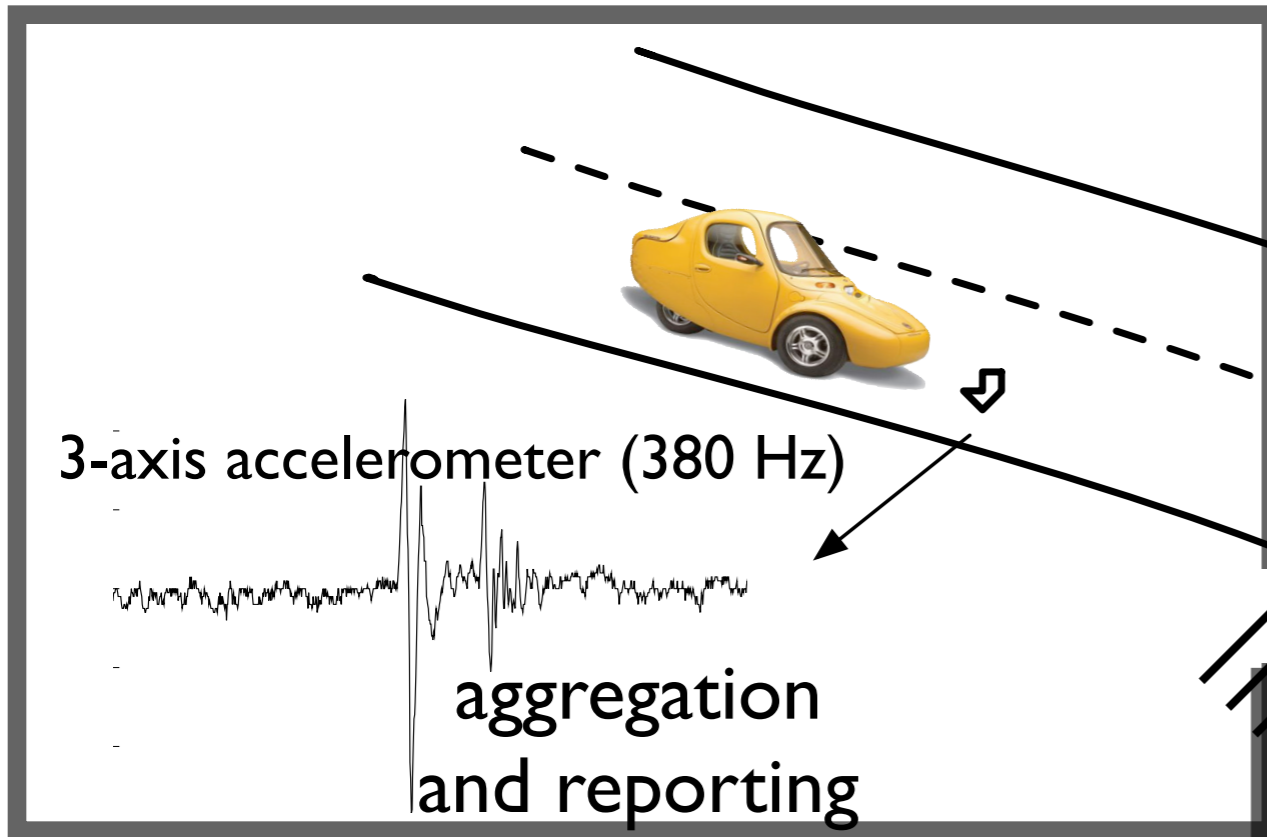


- road decay unavoidable, hard to predict
- current monitoring methods costly/ineffective

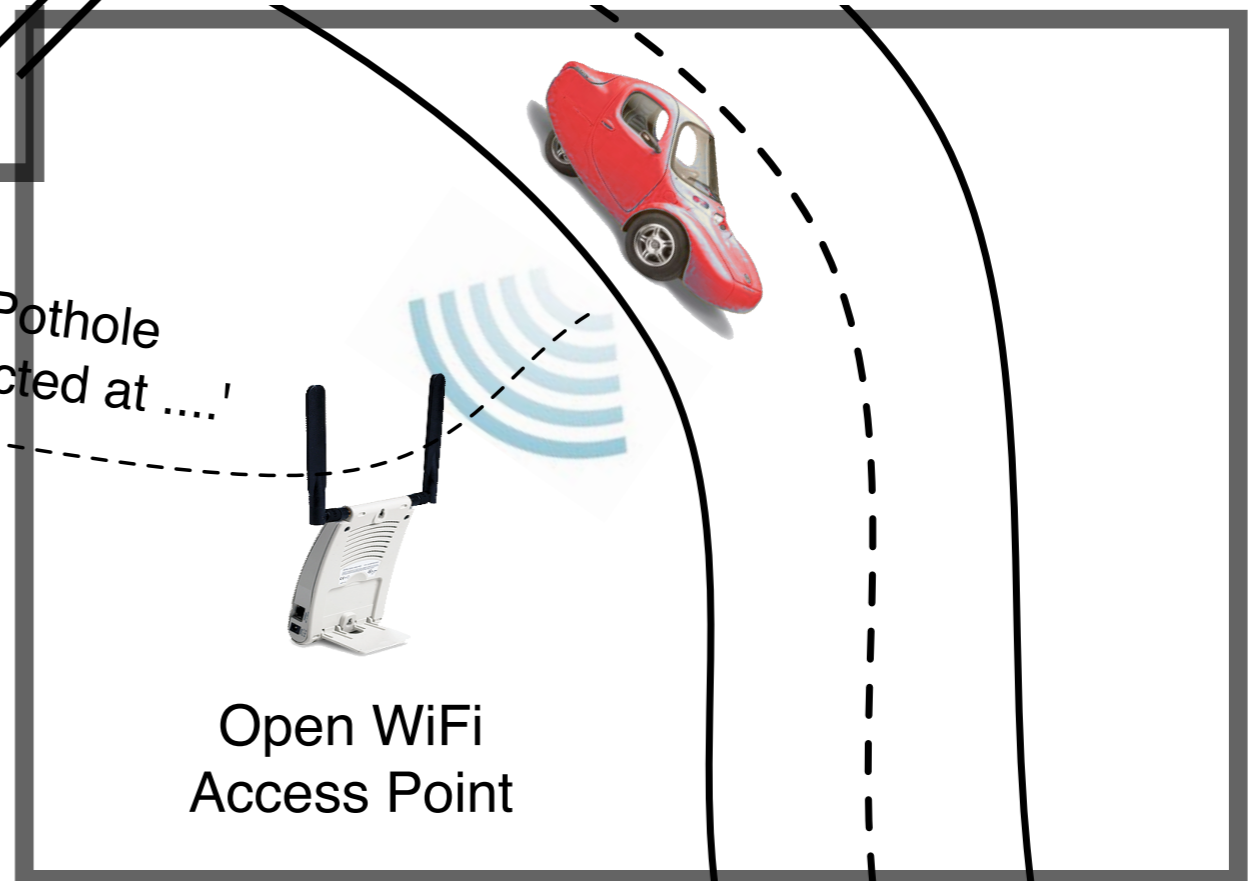
the Pothole Patrol

GPS localization

opportunistic accelerometer sensing

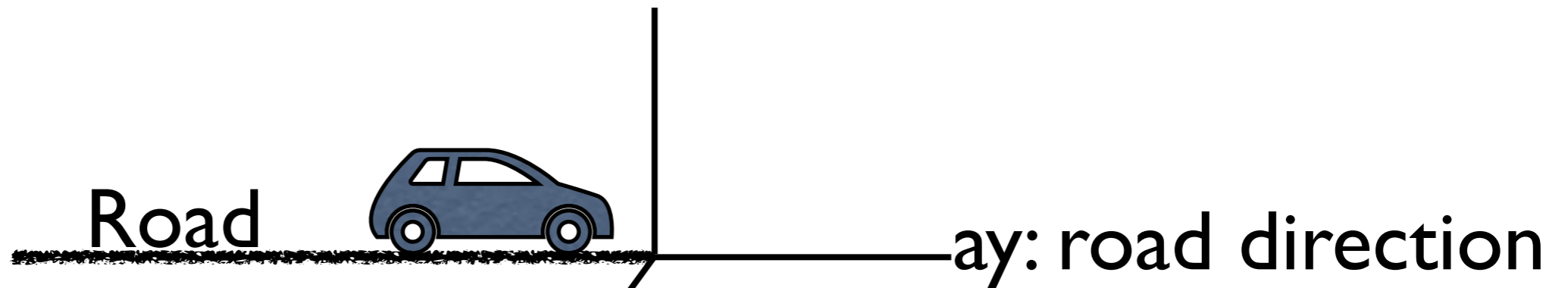


opportunistic data upload



Acceleration vector

a_z : perpendicular to road plane



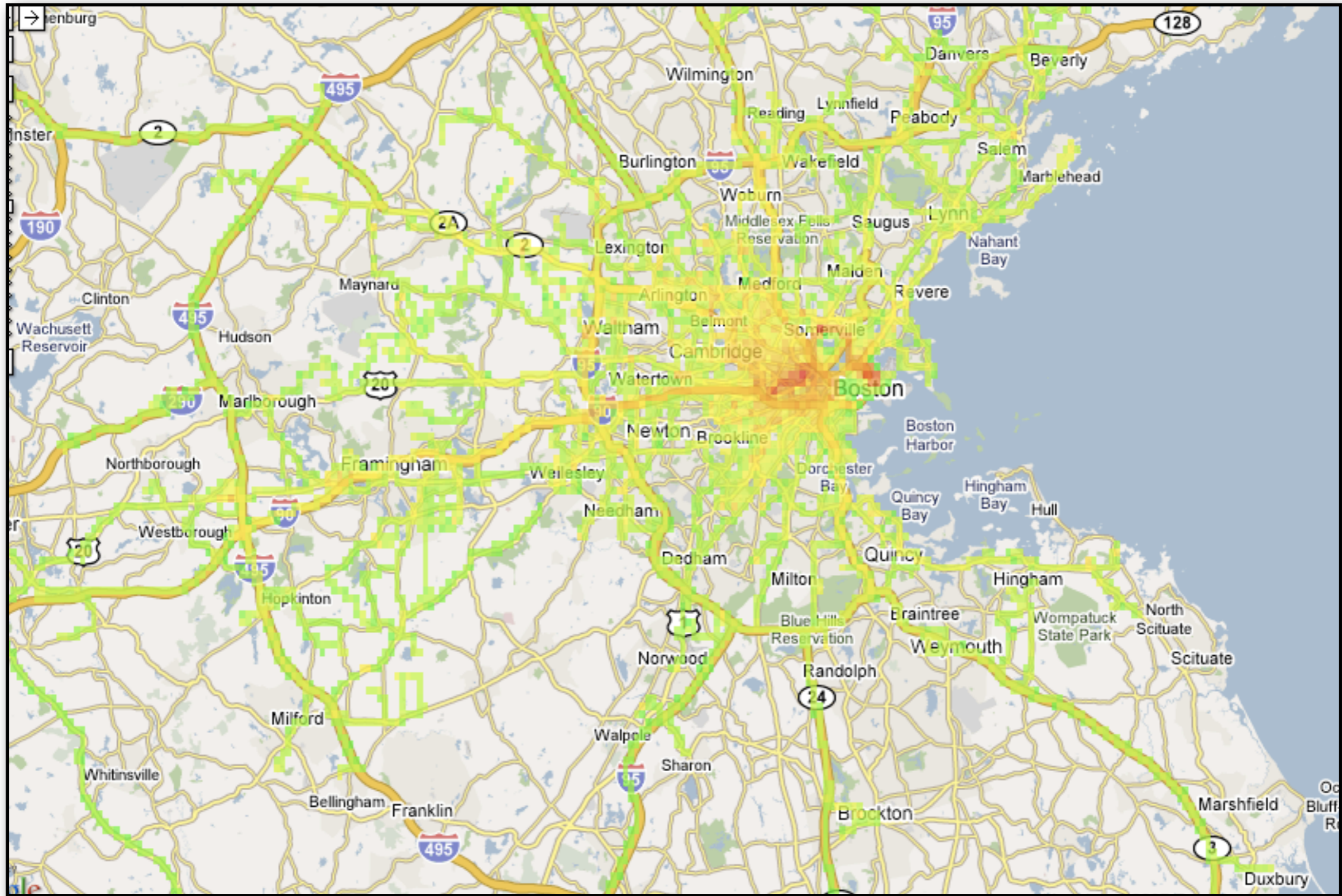
a_x : on road plane, perpendicular to road

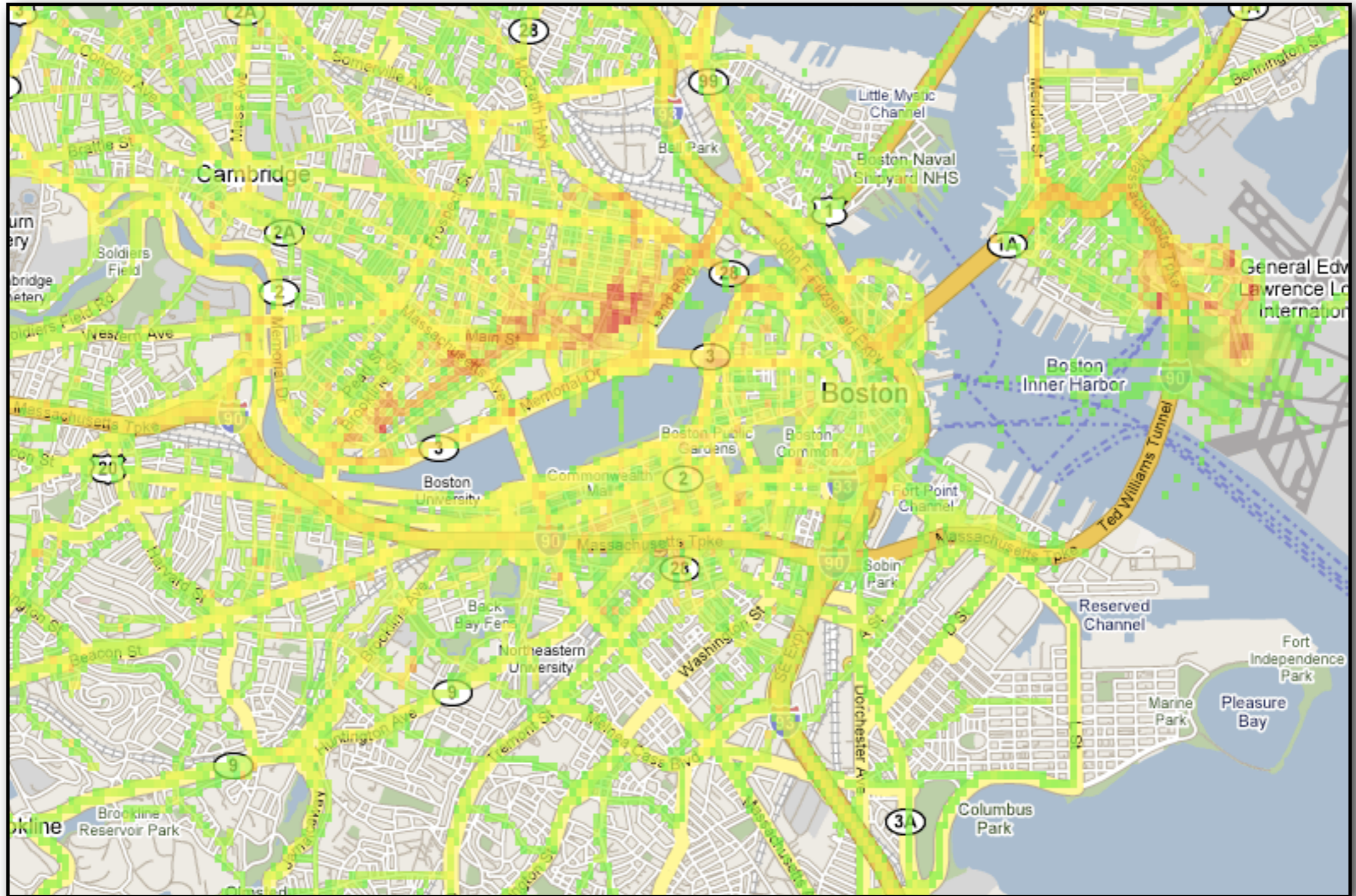
experimental platform

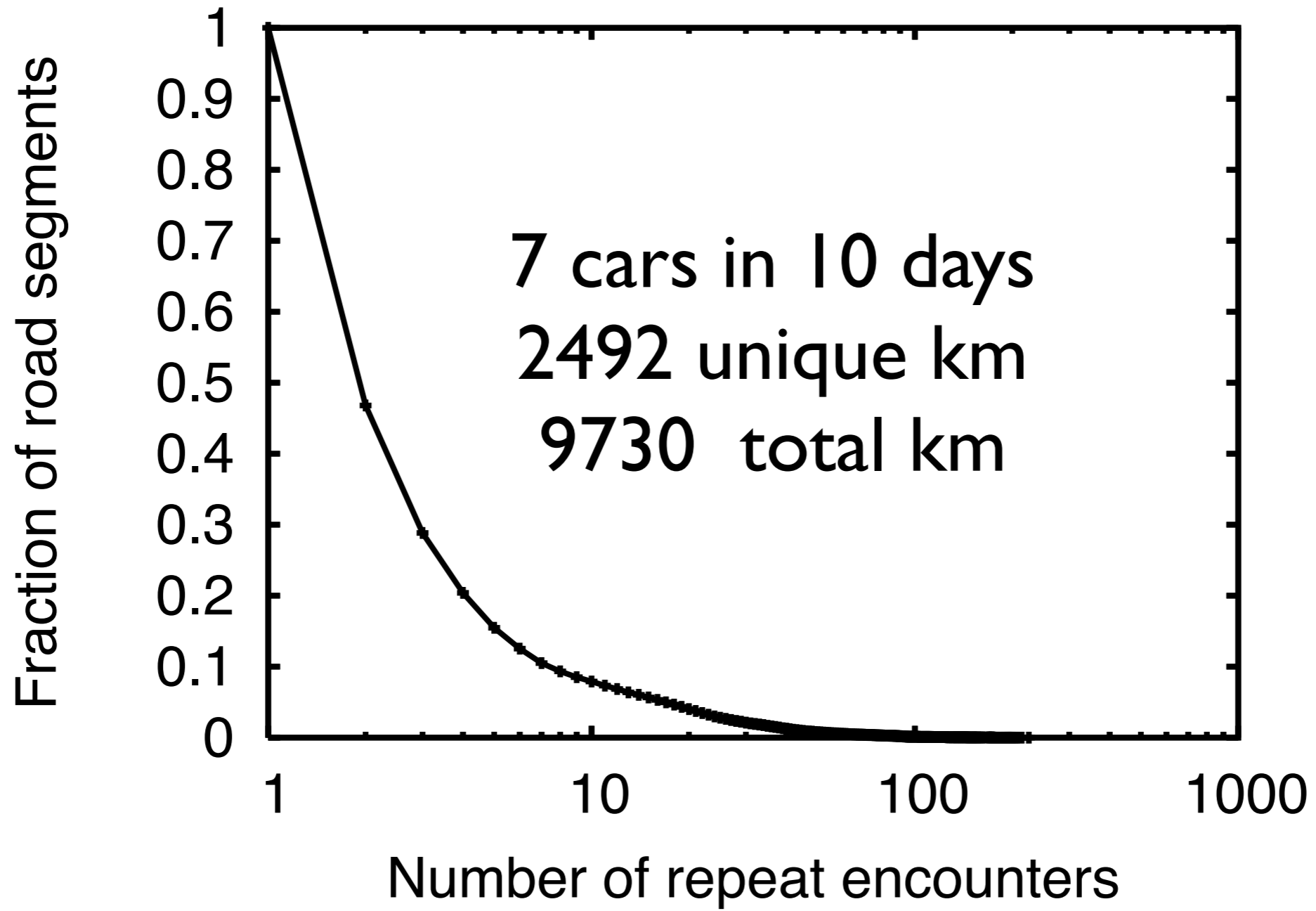
- 7 Boston/Cambridge taxis
- small computer in glove box
- 380 Hz 3-axis accelerometer
- 802.11a/b/g wireless interface
- GPS receiver on roof
- $\langle \text{time, location, heading, speed, } a_x, a_y, a_z \rangle$



wide-area sensing

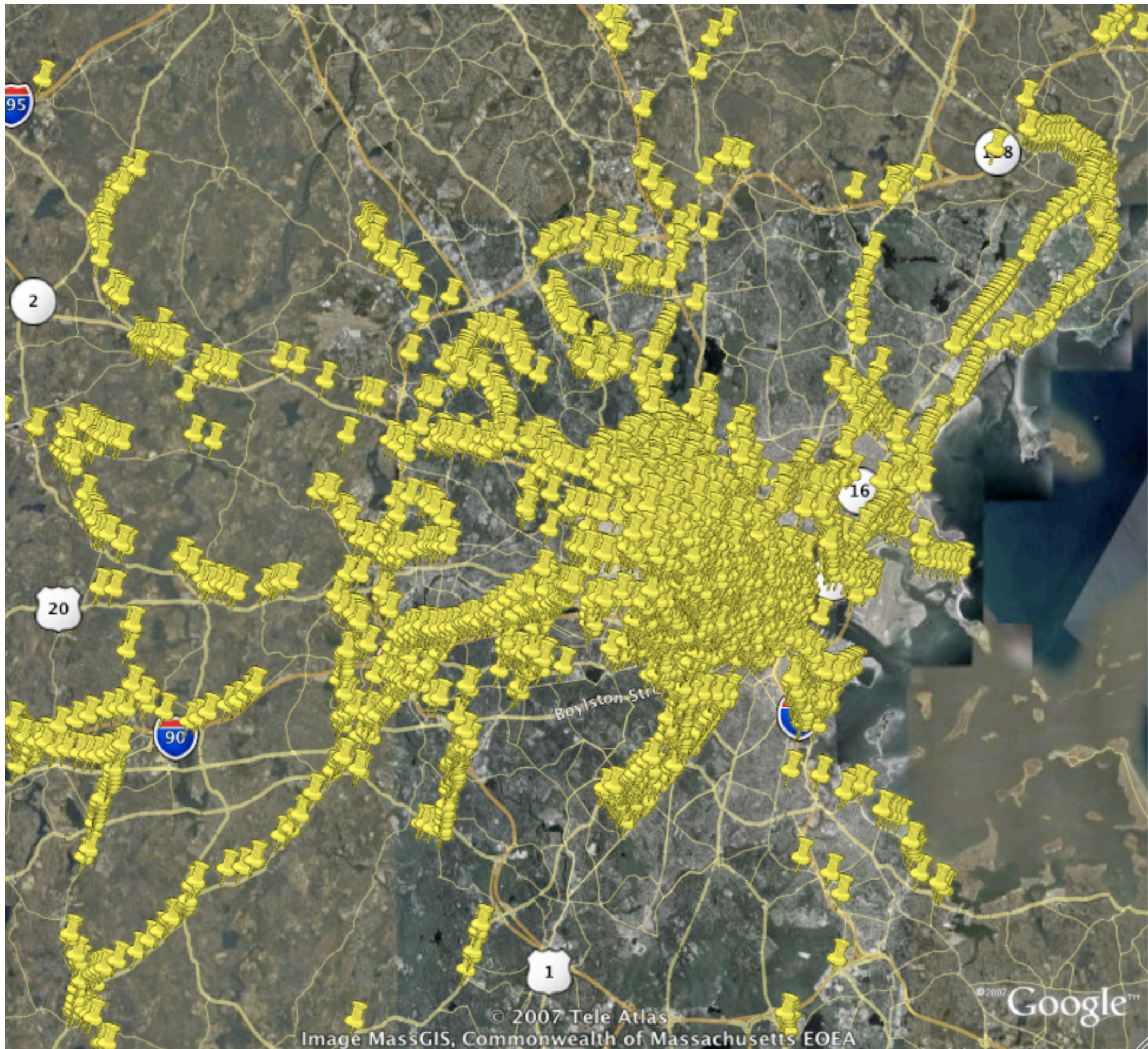




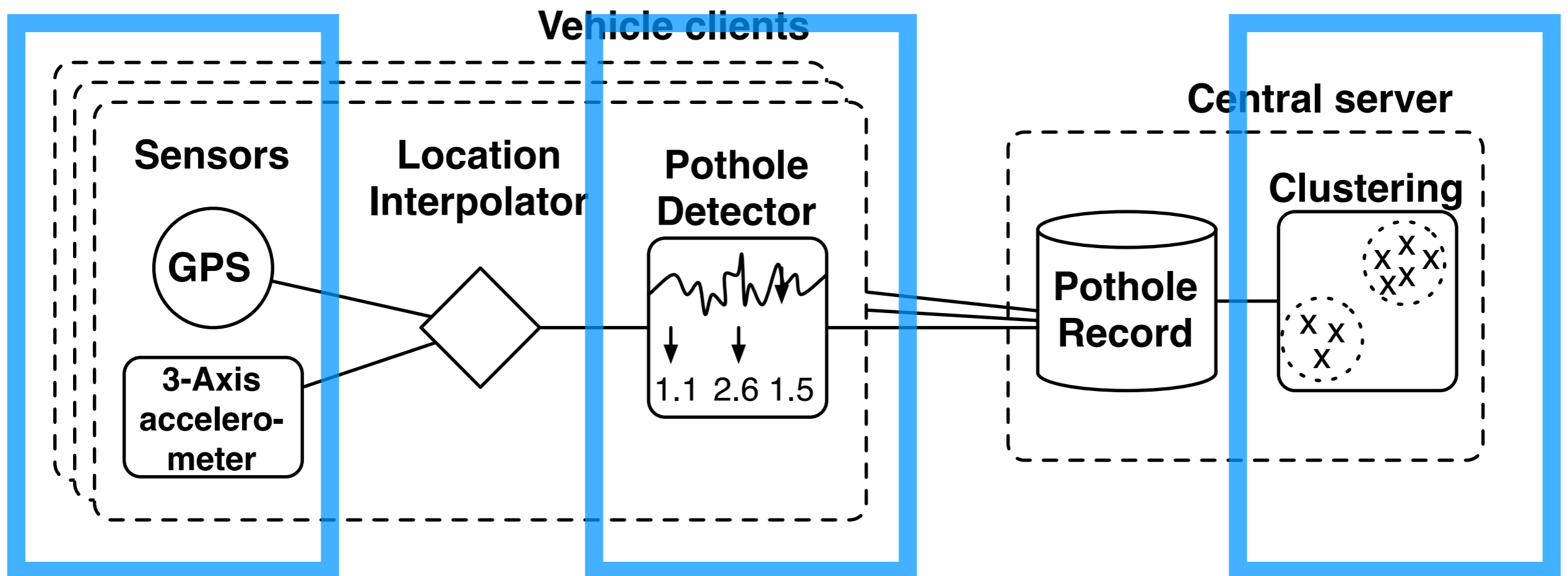


open WiFi connectivity





P² architecture



sensor placement

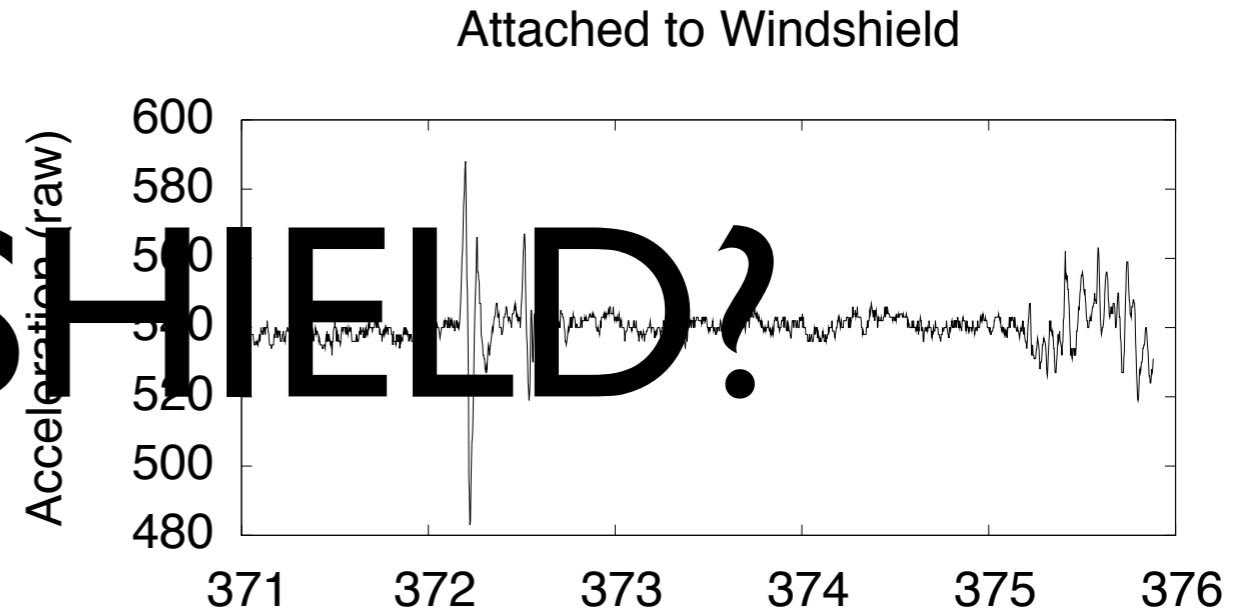


try to stay
inside vehicle

- highly accurate
- difficult mounting
- extreme exposure

- very clean signal
- 'gold standard'
- difficult to mount

WINDSHIELD?



Attached to Dashboard

Acceleration (raw)

Time into trace (sec)

• good signal

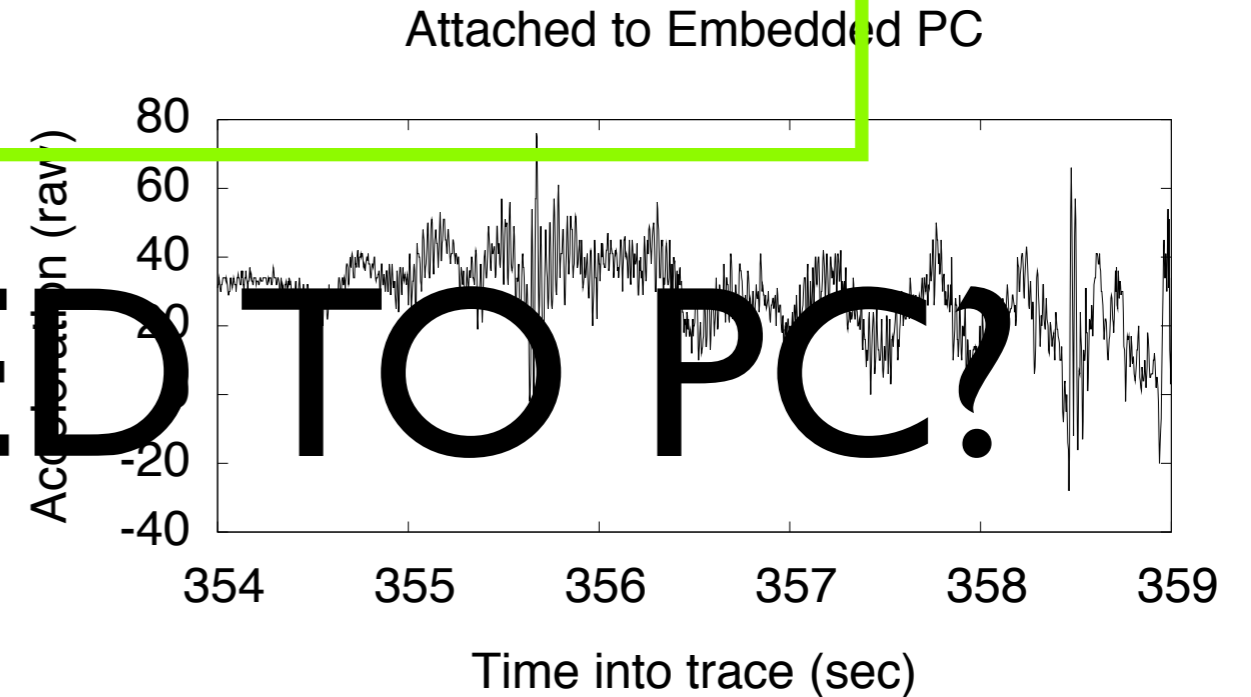
• easy to mount?

• out of the way

DASHBOARD?

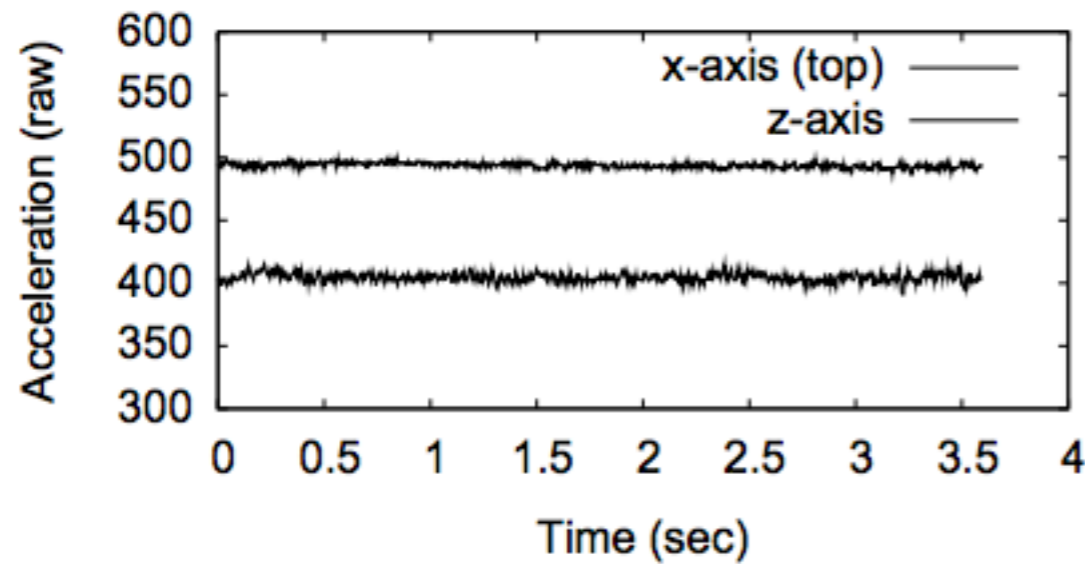
- very poor signal
- no mounting necessary

ATTACHED TO PC?

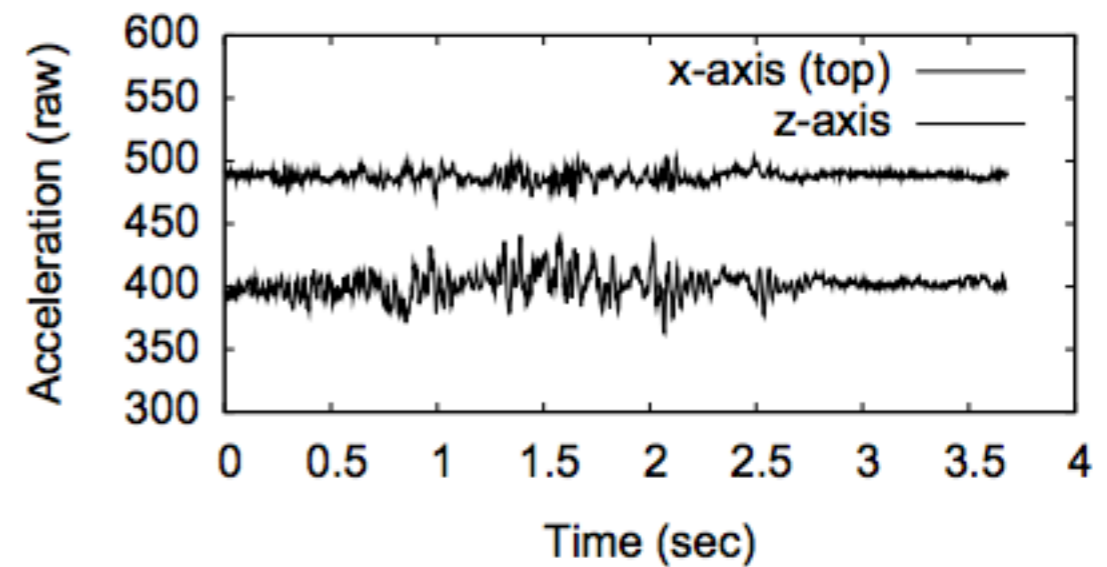


challenge: “pothole” v. “not pothole”

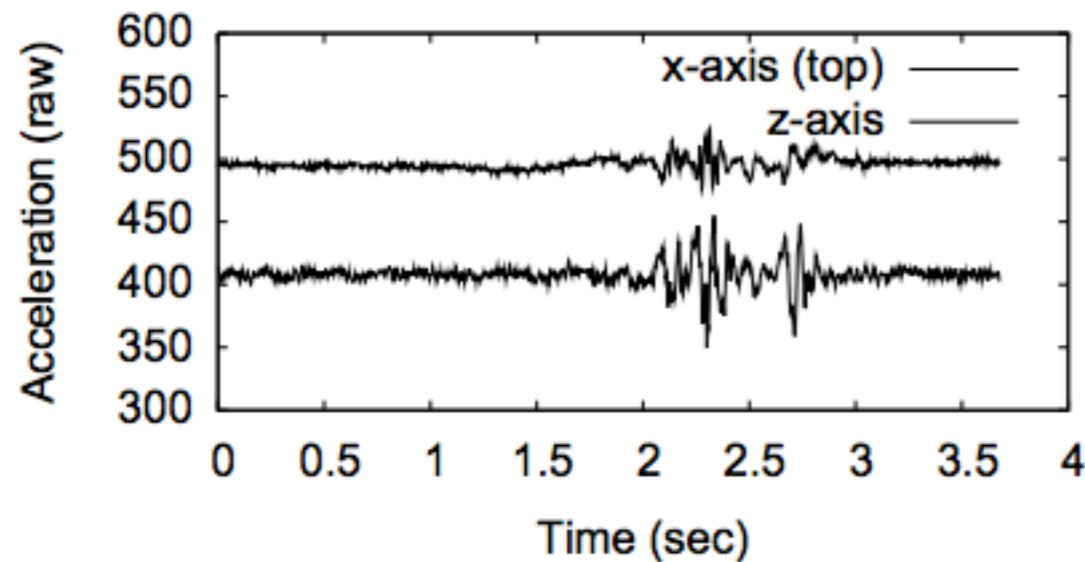
Smooth Road



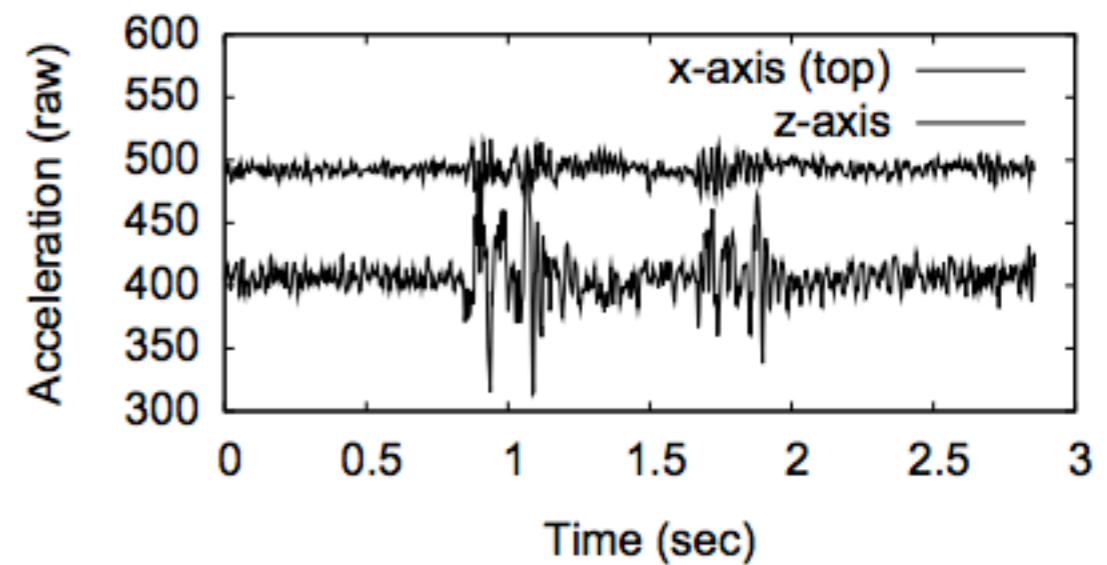
Rail Crossing



Pothole

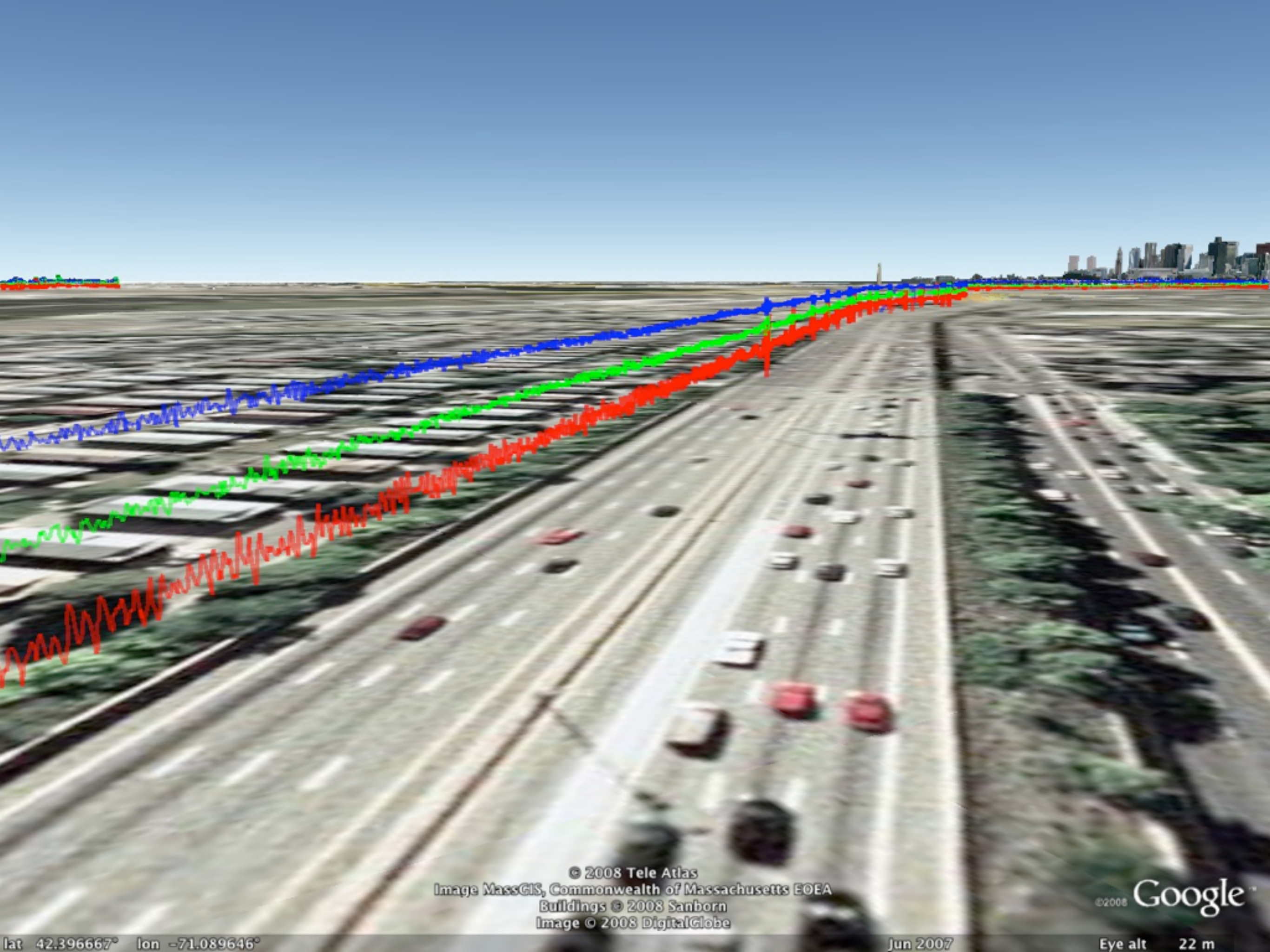


Expansion Joint



pothole v. not pothole





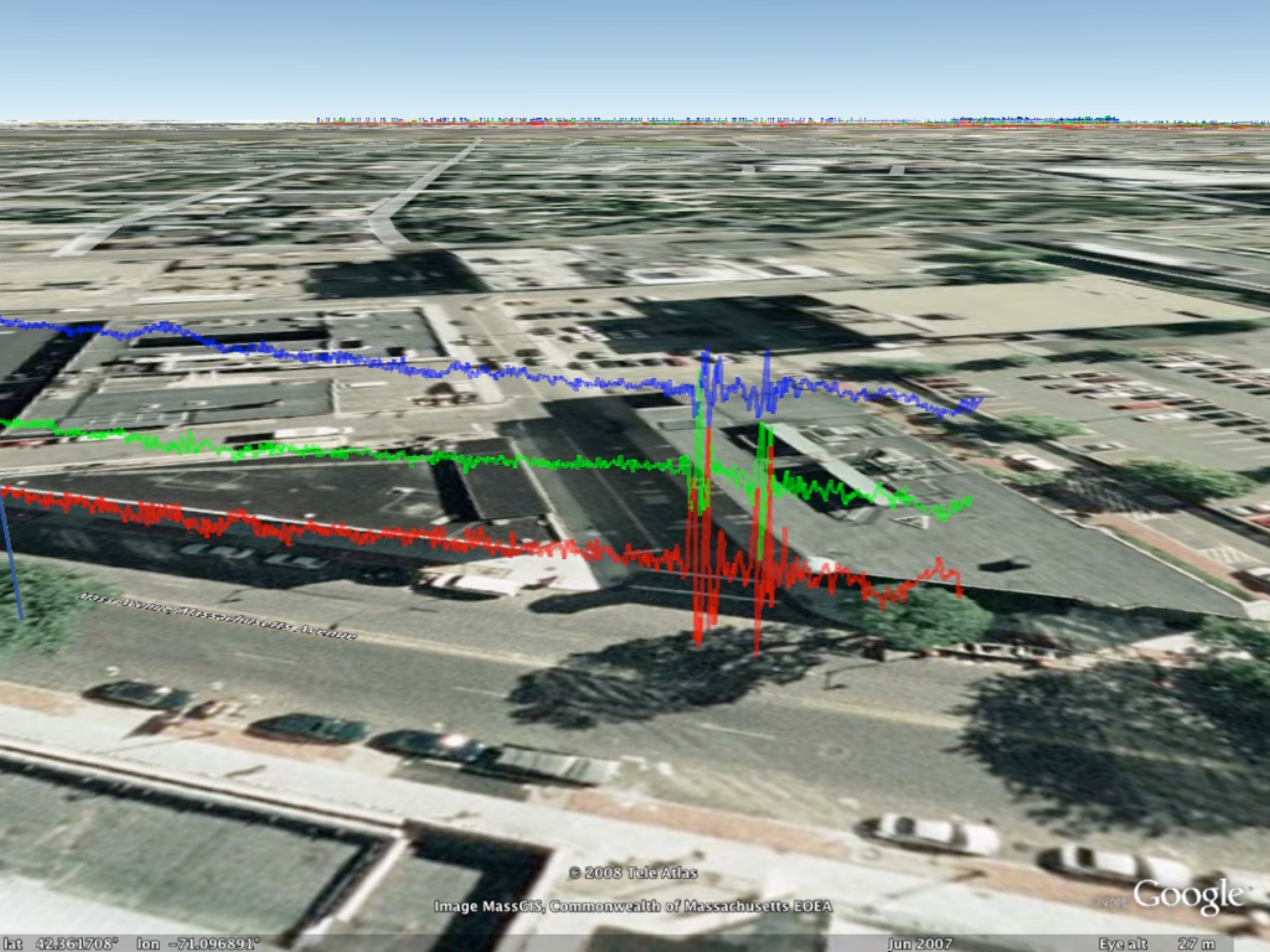
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lat 42.396667° lon -71.089646°

Jun 2007

Eye alt 22 m



1000 Avenue Massachusetts Avenue

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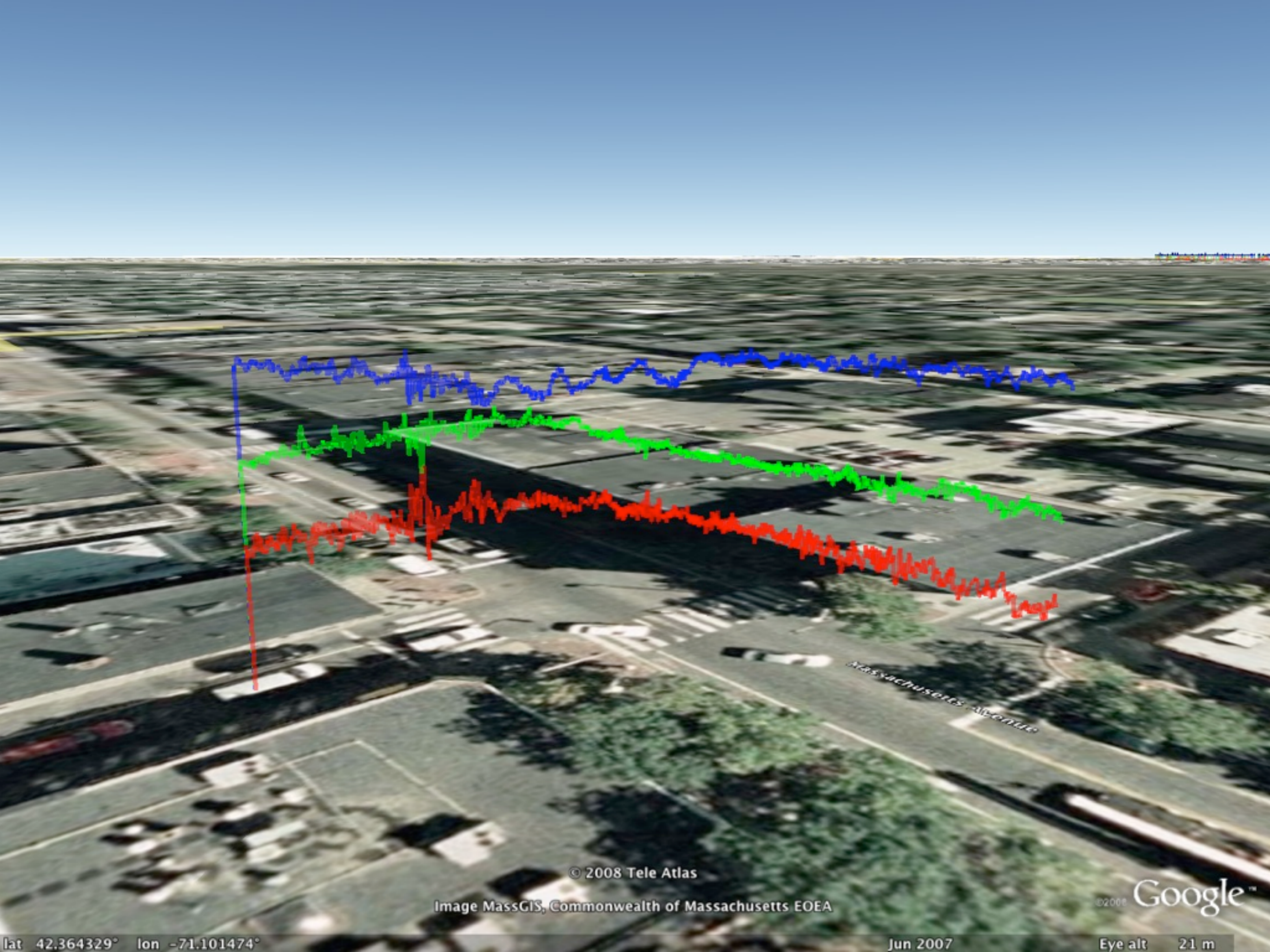
Image MassGIS, Commonwealth of Massachusetts EOEAA

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lat 42.361708° lon -71.096891°

Jun 2007

Eye alt 27 m



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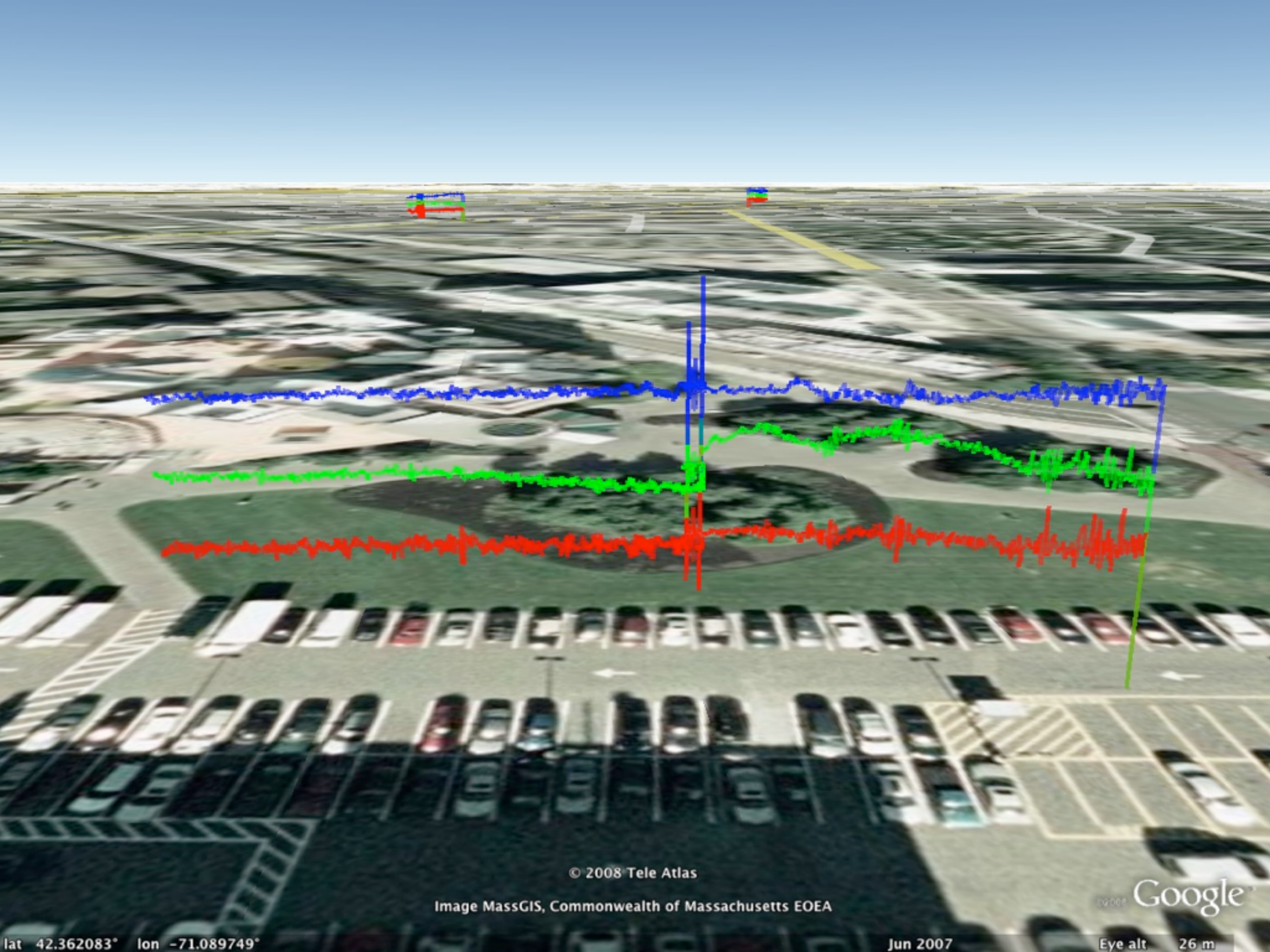
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lat 42.364329° lon -71.101474°

Jun 2007

Eye alt 21 m



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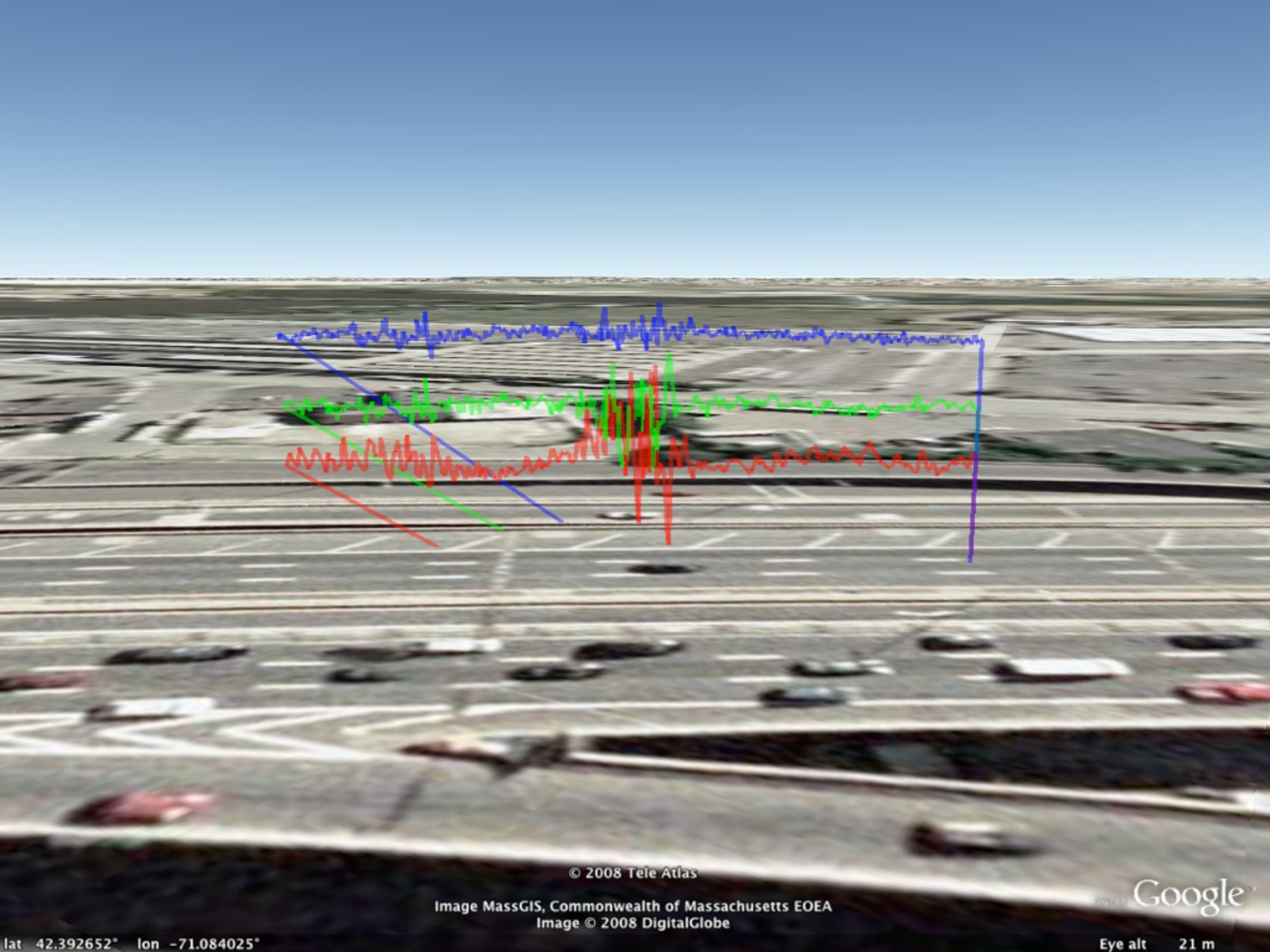
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Jun 2007

Eye alt 26 m



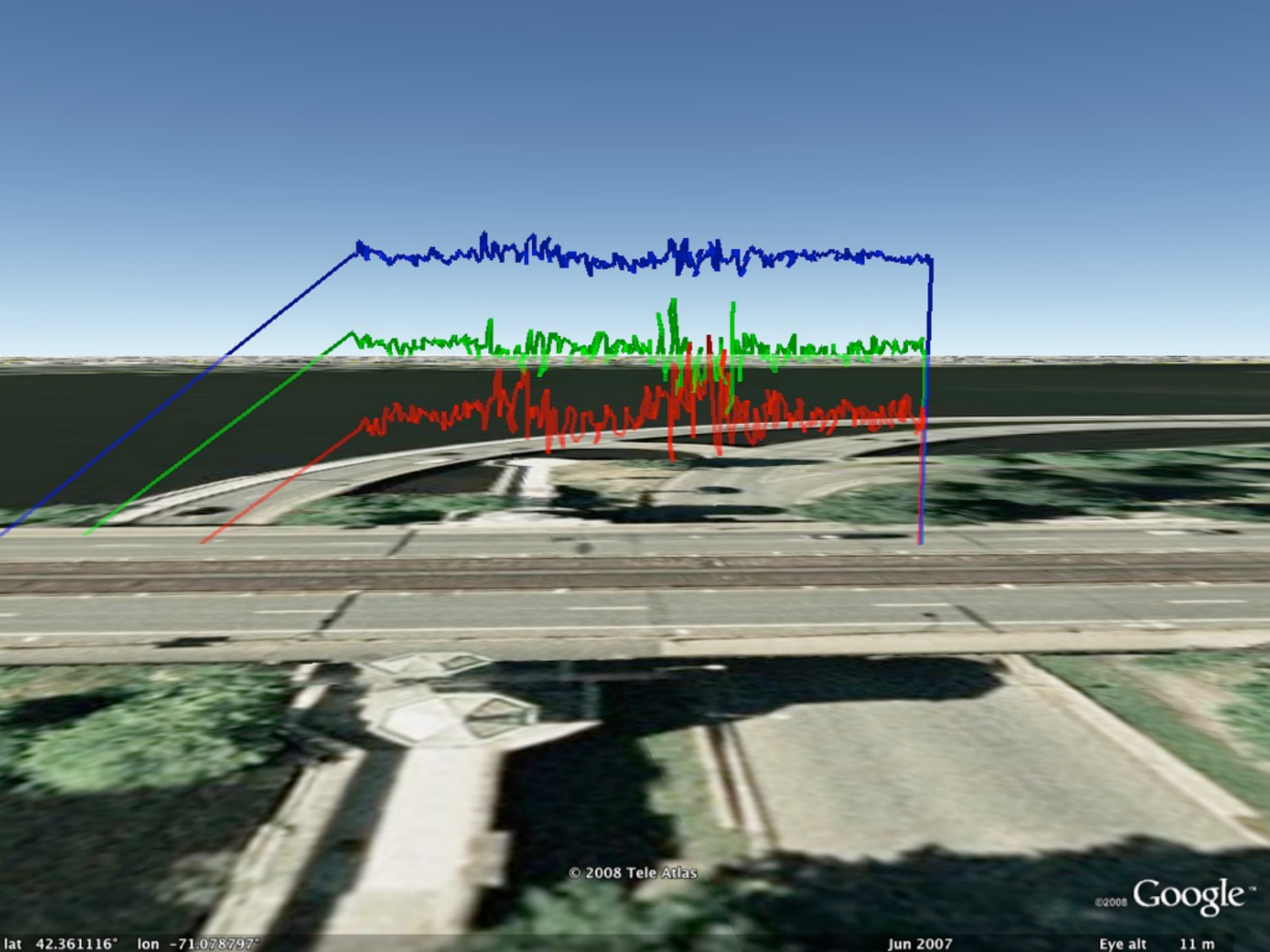
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lat 42.392652° lon -71.084025°

Eye alt 21 m



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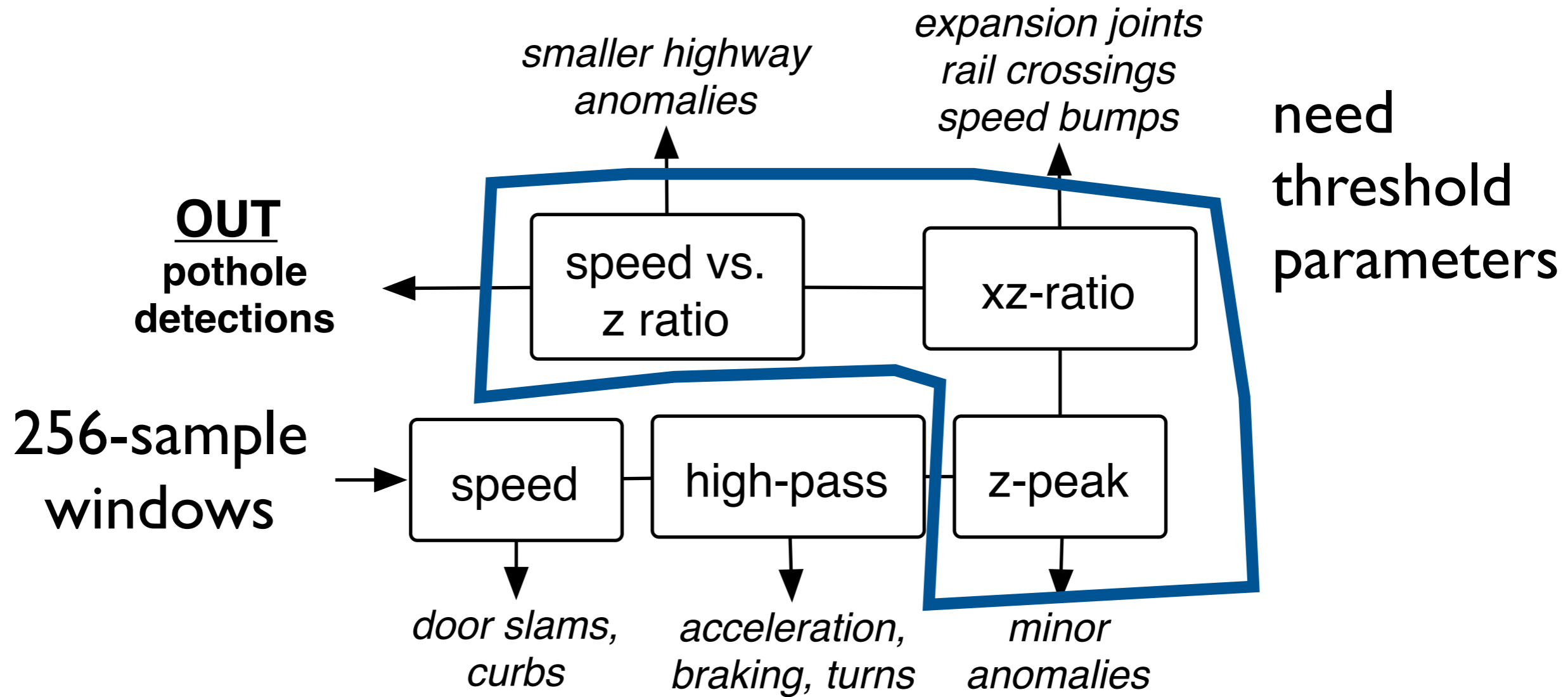
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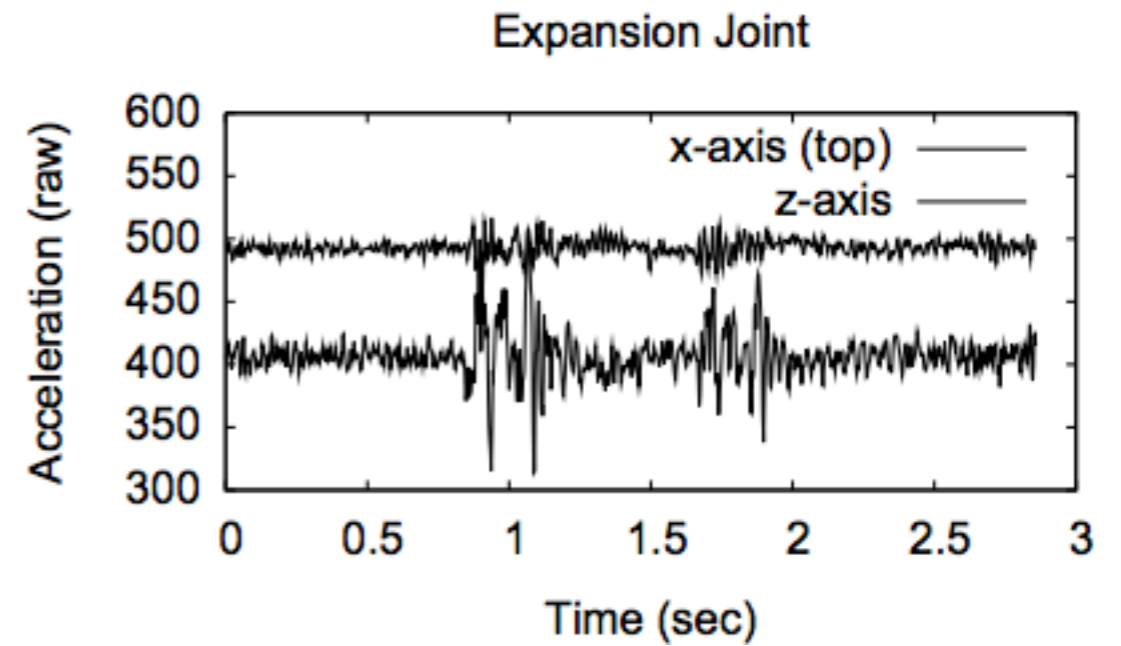
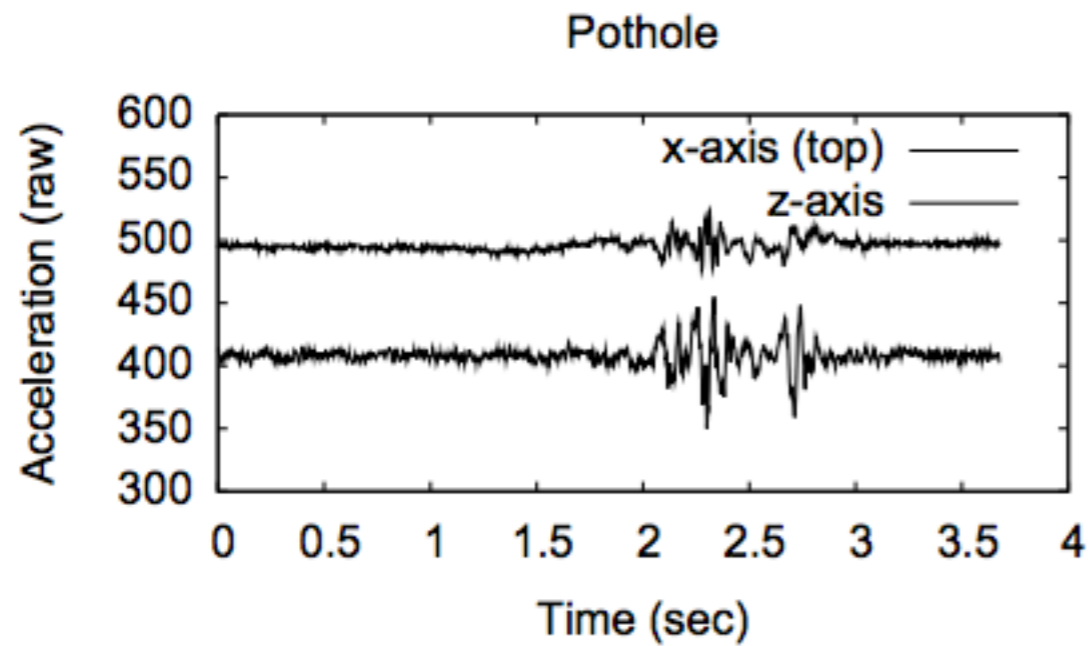
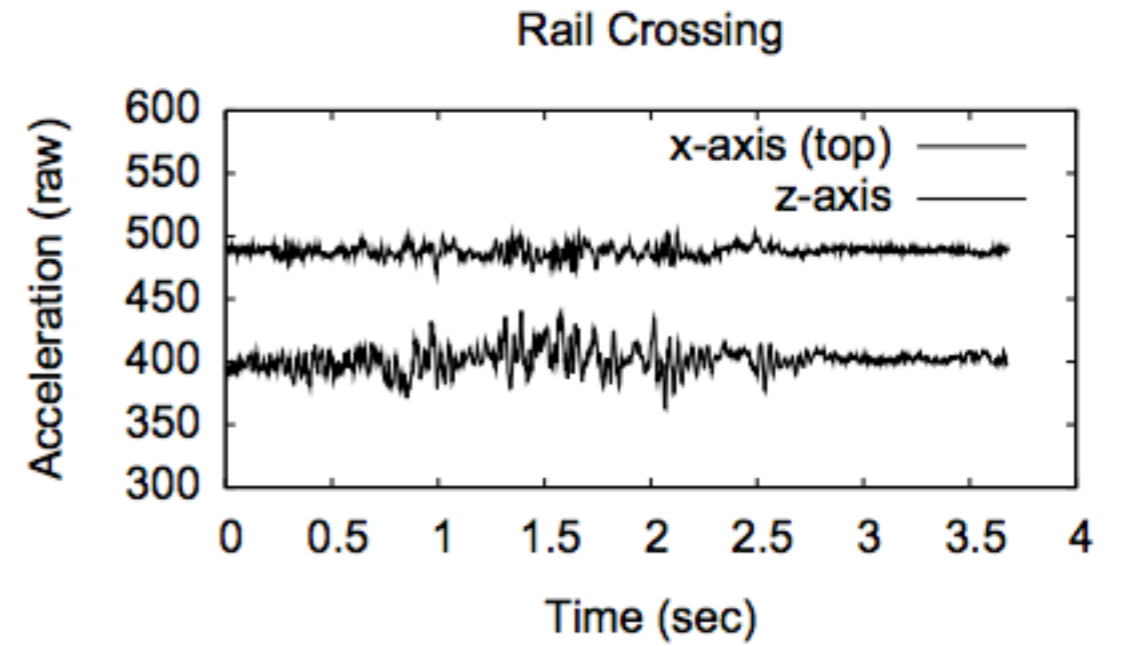
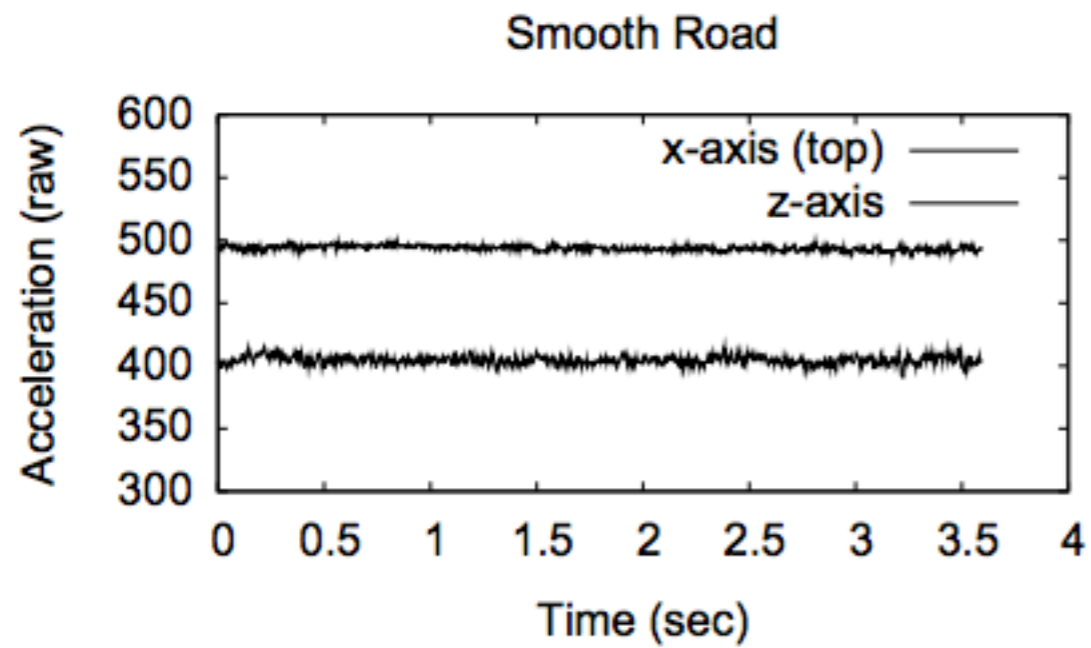
Jun 2007

Eye alt 11 m

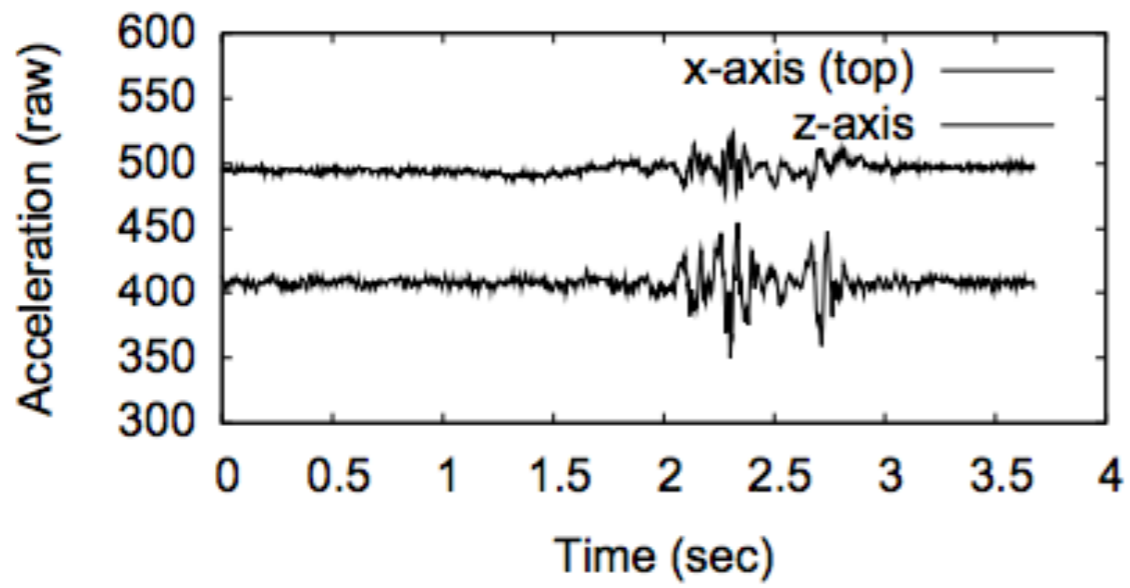
P² detector



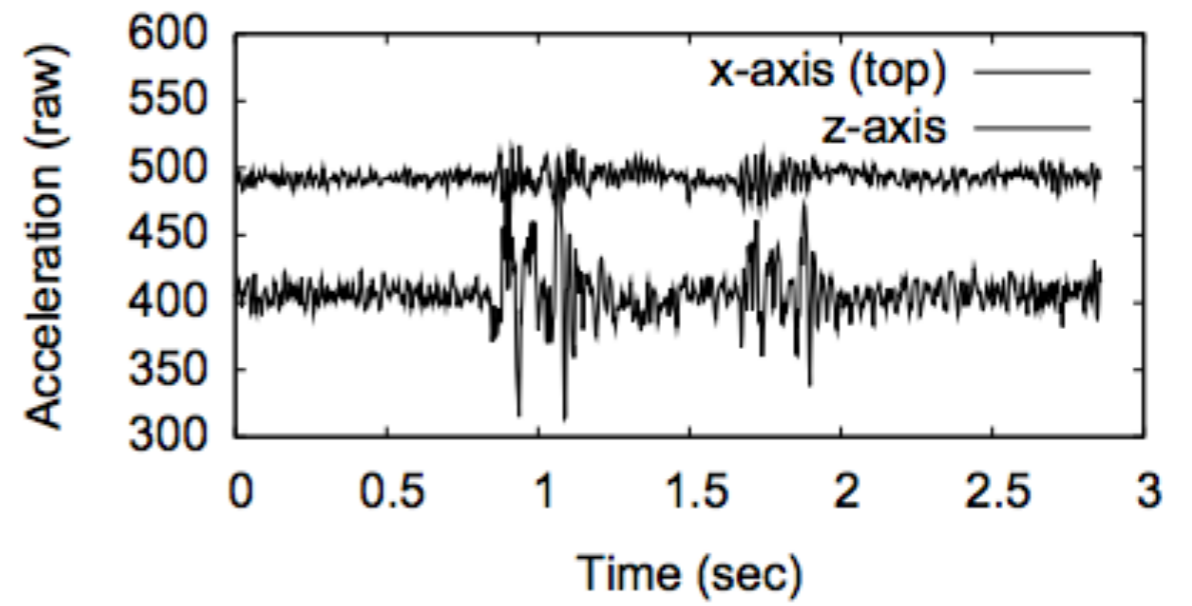
Events usually of much shorter duration than 256 samples



Pothole



Expansion Joint



hand-labeled training data

- **Smooth road (SM):** Segments of road surface that are considered smooth.
- **Crosswalks and Expansion Joints (CWEJ):** Crosswalks using extra-thick paint, brick, strips of pavers, or raised dots. Metal expansion joints in bridges and overpasses.
- **Railroad Crossing (RC):** Train tracks. Such crossings can be jarring, and are sometimes confused for a disturbed road surface.
- **Potholes (PH):** Missing chunks of pavement, severely sunk in or protruding manhole covers, other significant road surface anomalies.
- **Manholes (MH):** Manhole covers and other equipment in the road that are nearly flush with the road surface. Moderate cracking, sinking or bulging.
- **Hard Stop (ST):** A rapid deceleration, sometimes with the familiar jerk at the end.
- **Turn (TU):** Turning a corner. This sometimes exhibits a rather violent acceleration profile.

training the detector

- manually label training samples

Type	Count	Percentage
Smooth road (SM)	64	23%
Potholes (PH)	63	23%
Manholes (MH)	59	21%
Railroad Crossing (RC)	18	6%
Crosswalk/Exp. Joint (CWEJ)	76	27%

loosely-labeled training

- needed to avoid over-training with unrepresentative manually curated data
- under-samples “smooth” roads
 - **Storrow Dr.** Heavily used four-lane parkway on the Boston side of the Charles River with several bridges, some potholes.
 - **Memorial Dr.** Heavily used four-lane parkway on the Cambridge side of the Charles River, good condition.
 - **Binney St.** A two-lane street with many sunk-in manholes and sealed cracks, one pothole.
 - **Hwy I-93** An 8 lane interstate highway that cuts through the center of Boston in good condition.
 - **Beacham St** A heavily trafficked back road in very poor condition.

training the detector

- pick an objective function

$$s(\mathbf{t}) = \mathit{corr} - \mathit{incorr}^2$$

- optimize over 3 threshold parameters
 - z-peak
 - xy-ratio
 - speed vs. z-ratio

detector performance

Class	After training on loosely labeled data	
	before	after
Pothole	88.9%	92.4%
Manhole	0.3%	0.0%
Exp. Joint	2.7%	0.3%
Railroad Crossing	8.1%	7.3%

E.g., 7.3% of detected “potholes” are railroad



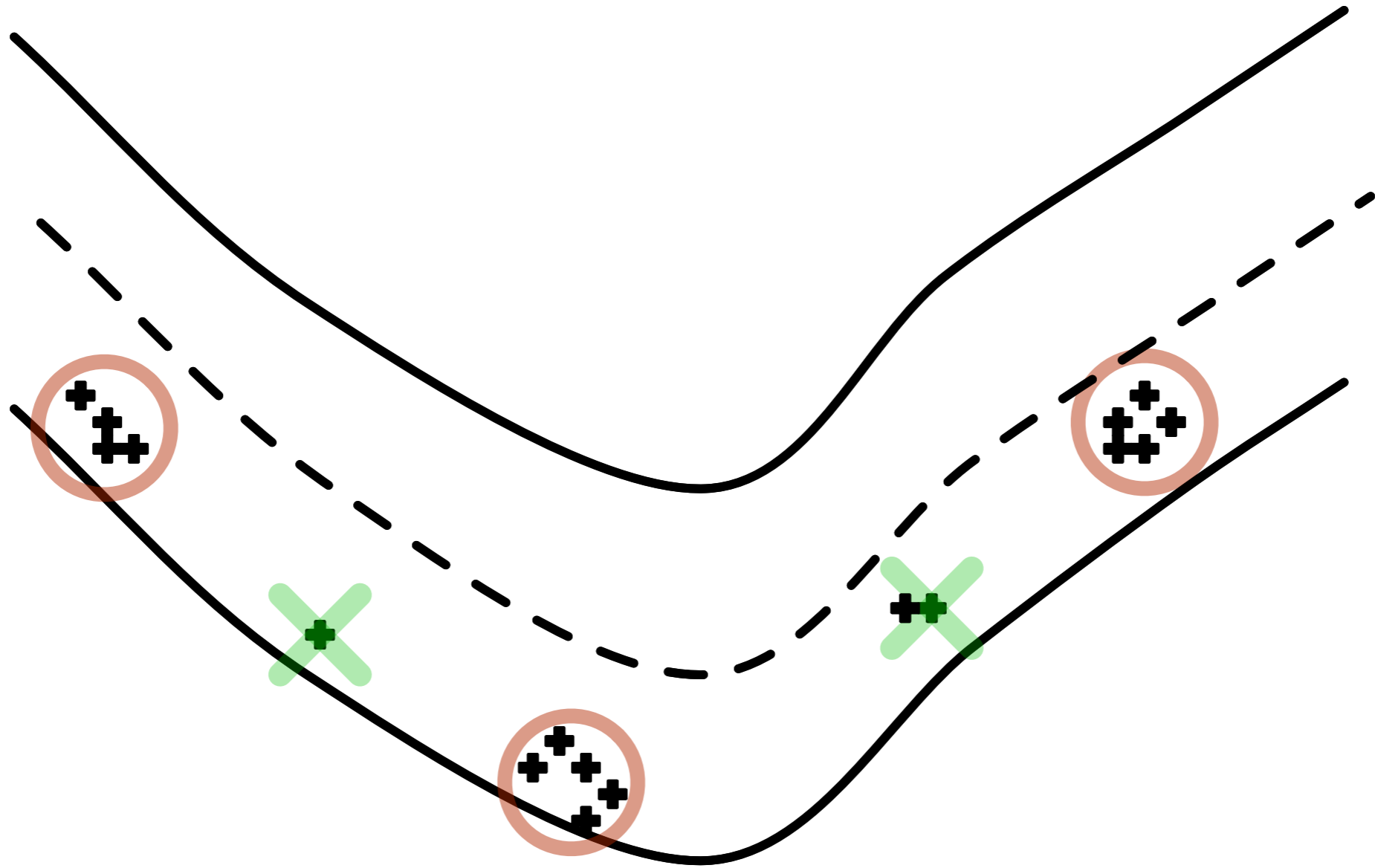
Note: Actual false positive rate is not 7.6%
Why?

estimating false +ve rate

Road	# potholes	#win	#det.	rate
Storrow Dr.	few	1865	3	0.16%
Memorial Dr.	few	1781	2	0.12%
Hwy I-93	few	2877	5	0.17%



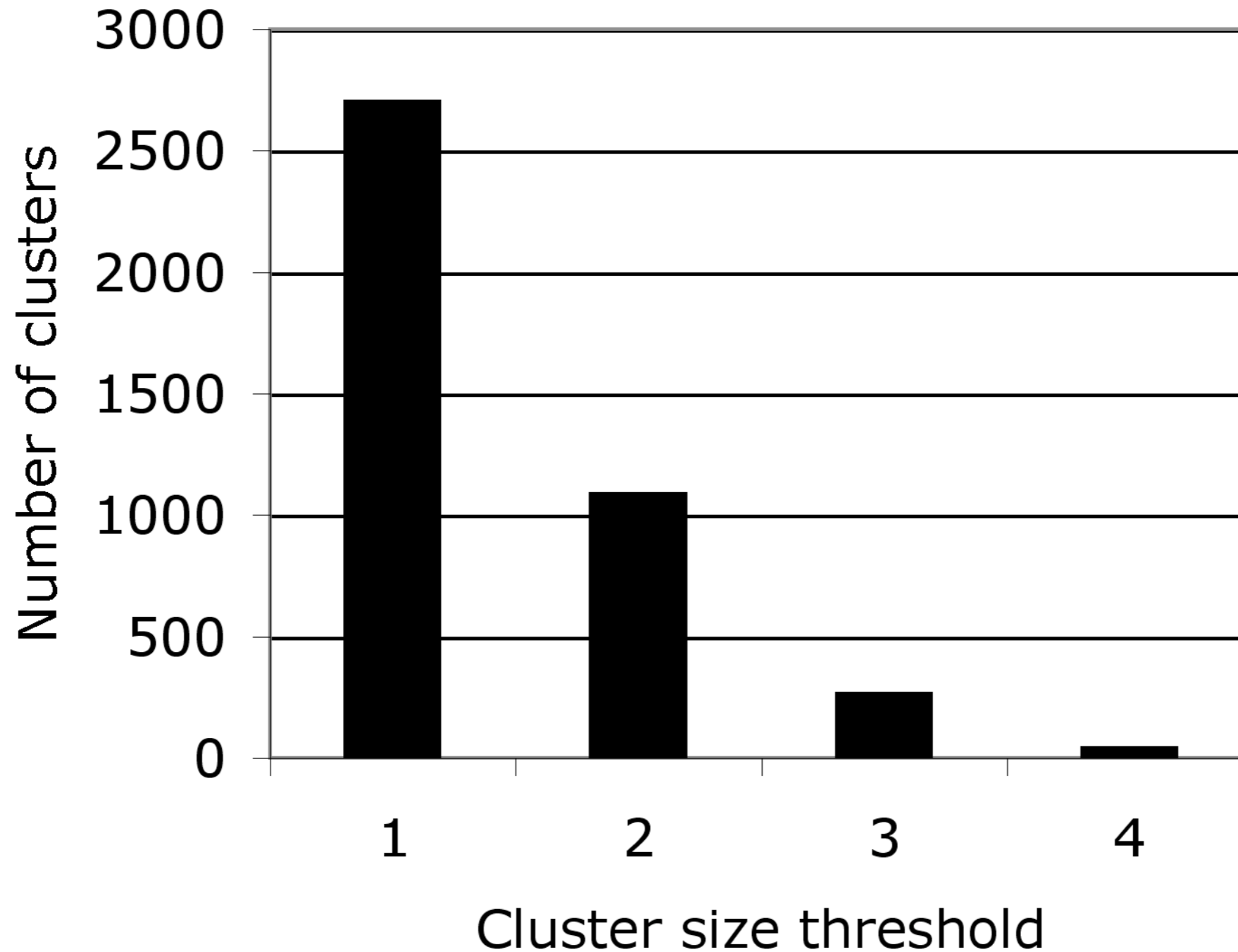
clustering

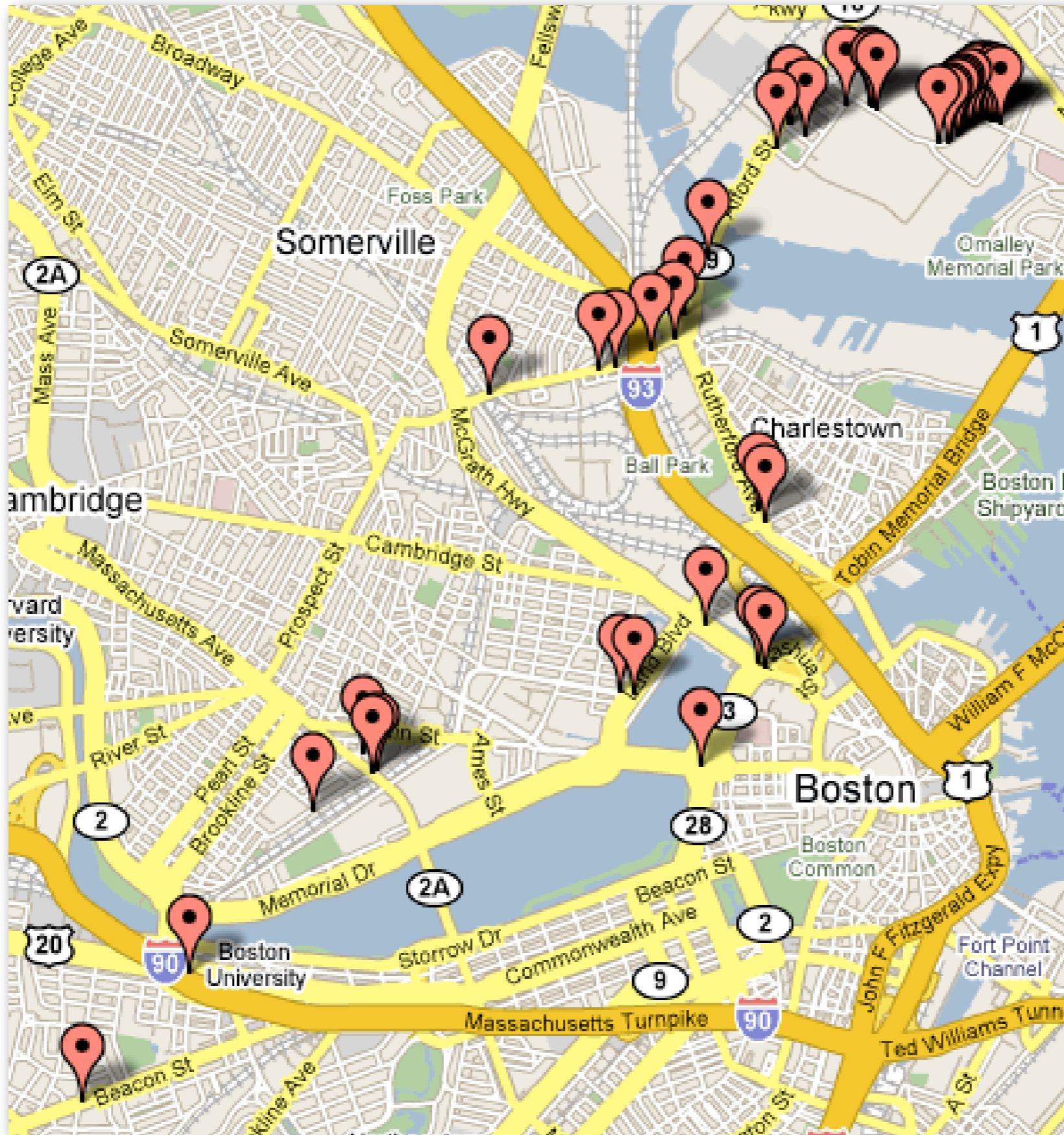


experiments

- 7 taxis over 10 days
- 9730 total km of road covered
- 2492 unique km of road covered
- 1.4 million sample windows
- 4131 severe detections in 2709 locations (after clustering)

impact of cluster size

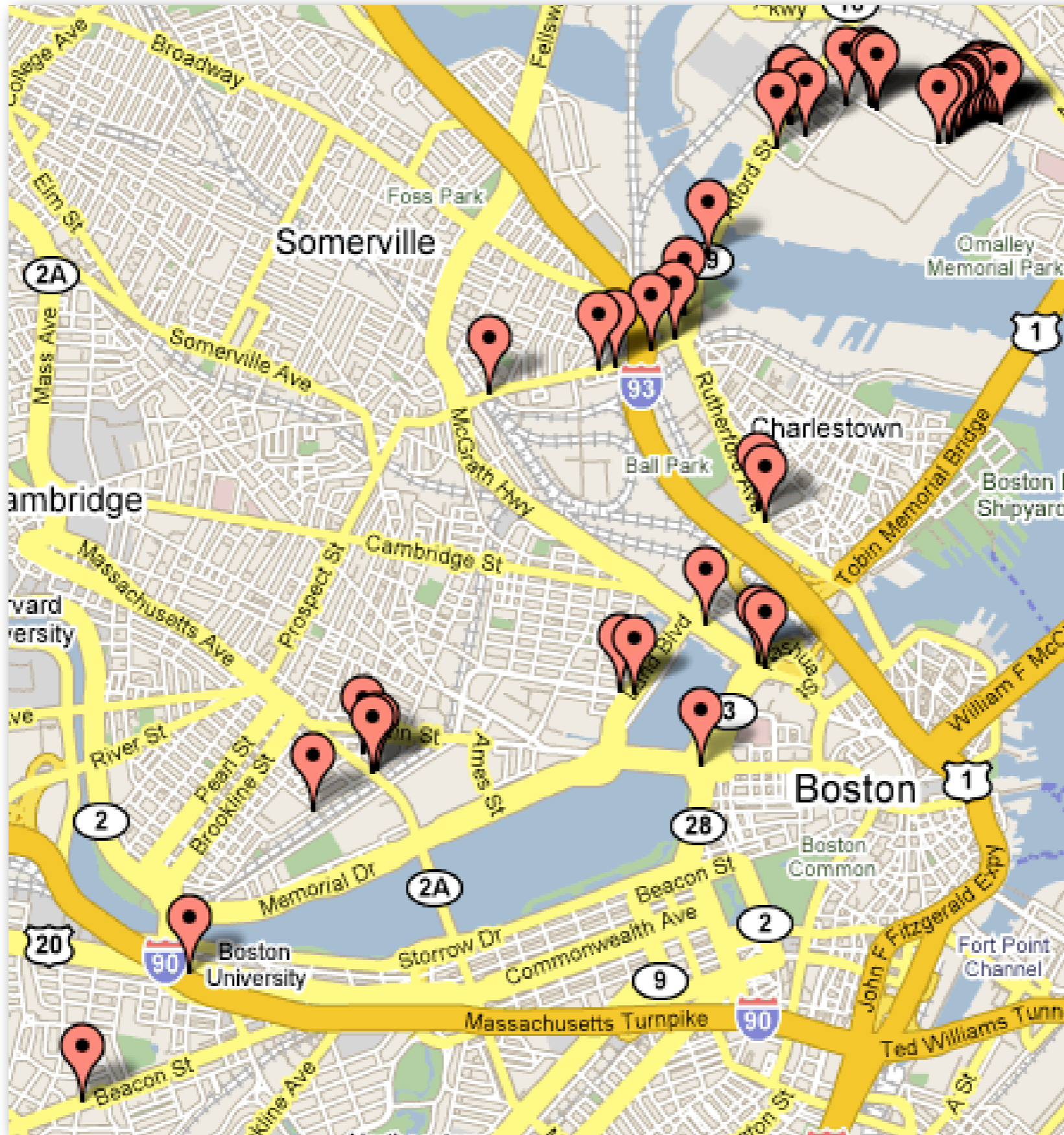


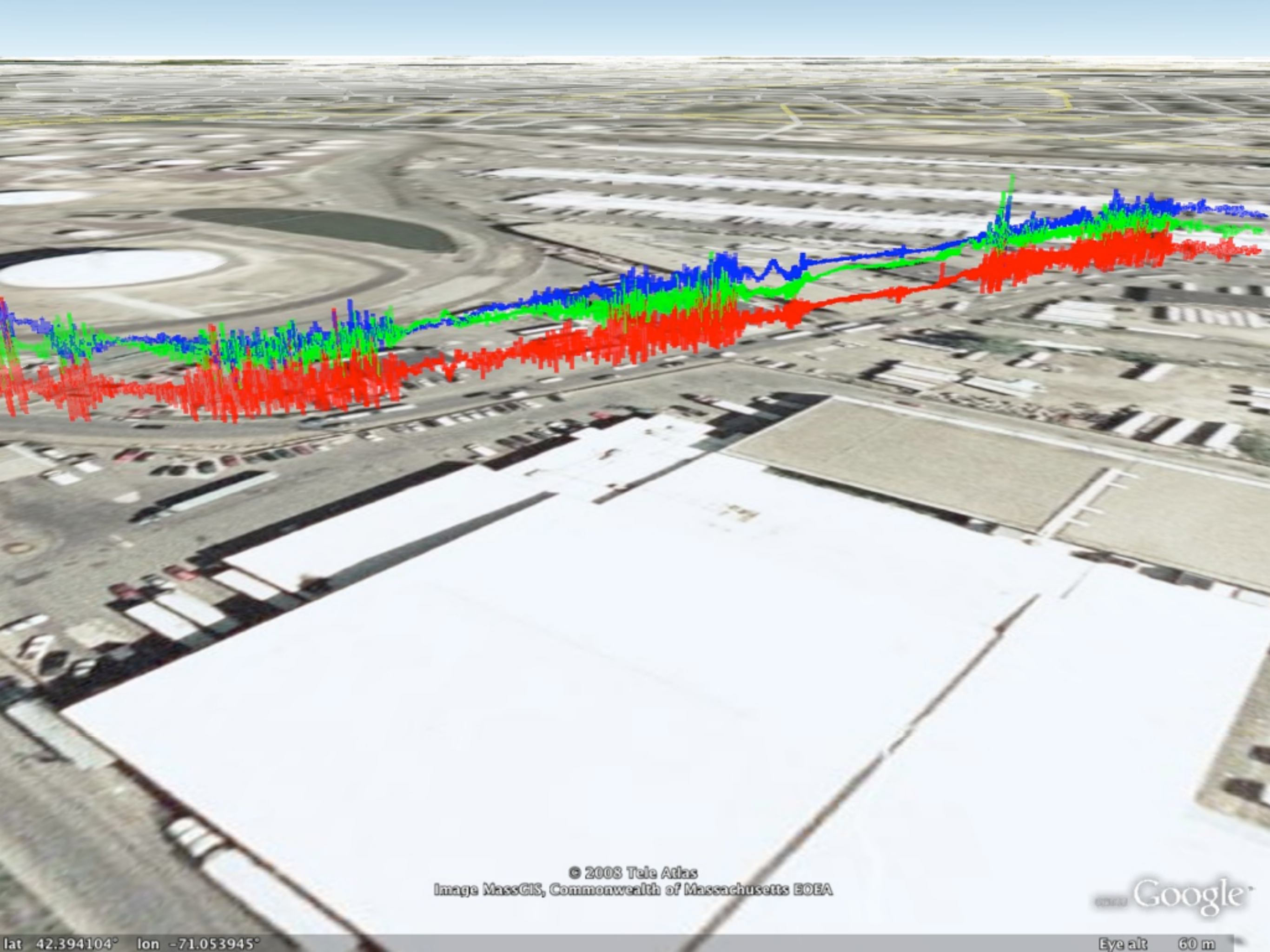


48 spot-checks

potholes	39
sunk-in manholes	3
railways and exp. joints	4
undetermined	2







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lat 42.394104° lon -71.053945°

Eye alt 60 m

P²: the Pothole Patrol

- automatic wide-area road quality monitoring
- use of opportunistic mobility
 - mobile sensing w/ delay-tolerant communication
 - machine learning classifier with labeled and loosely-labeled data
 - Data collection and curation is hard!
- low-cost approach to help solve a costly problem