

# The Pothole Patrol

6.S062 Spring 2018

Lecture 8

3/6/2018

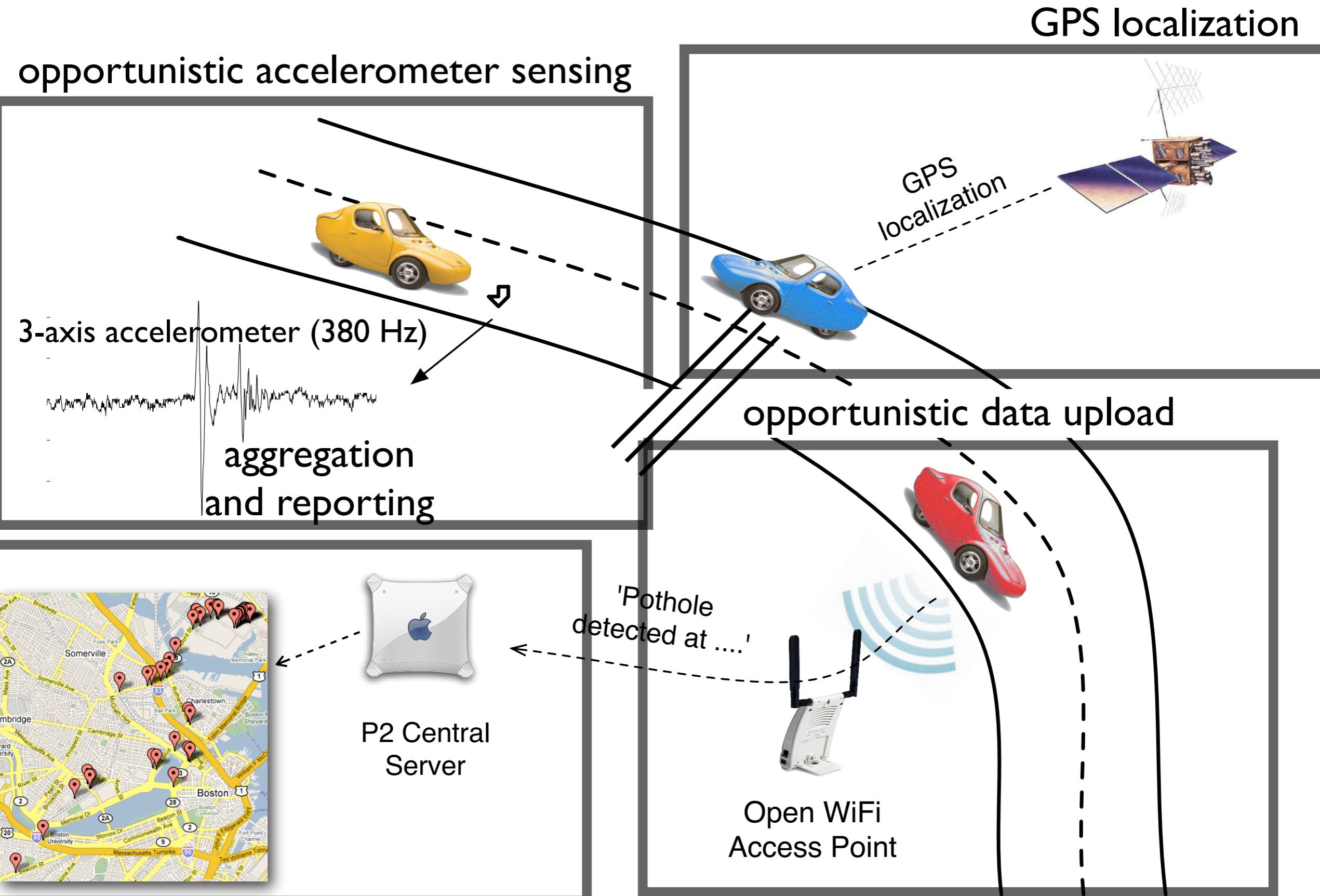
Balakrishnan & Adib

Based on Slides from Jakob Eriksson



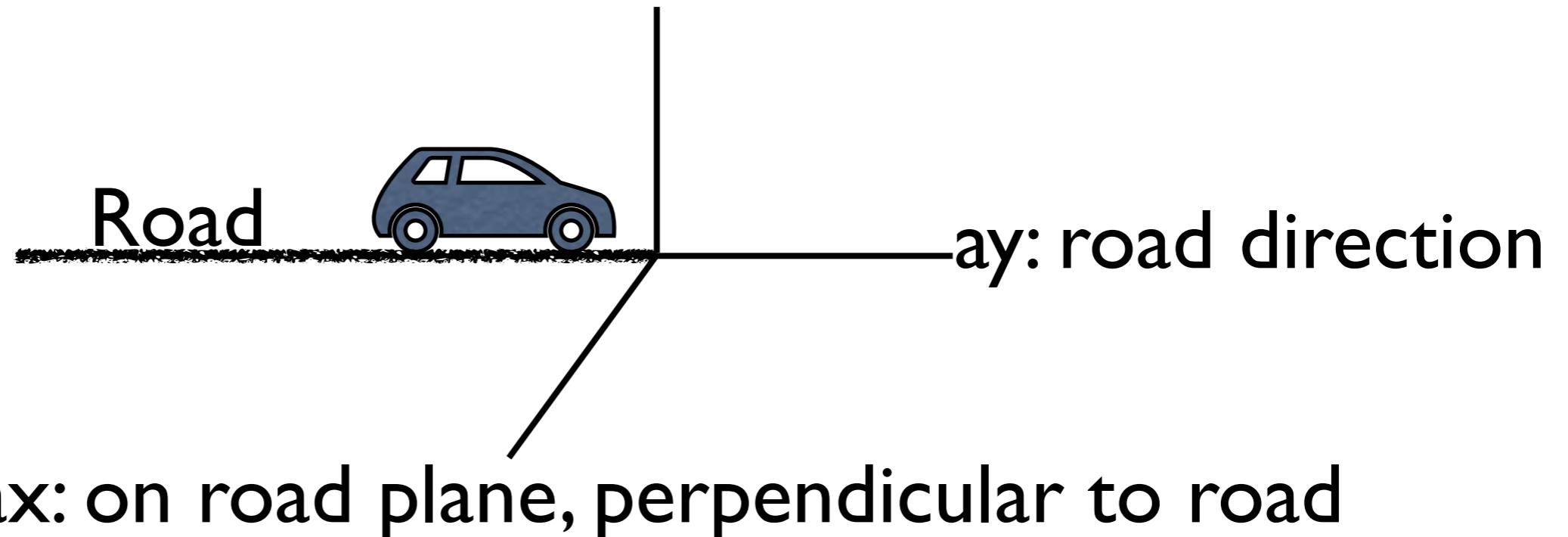
- road decay unavoidable, hard to predict
- current monitoring methods costly/ineffective

# the Pothole Patrol



# Acceleration vector

$az$ : perpendicular to road plane



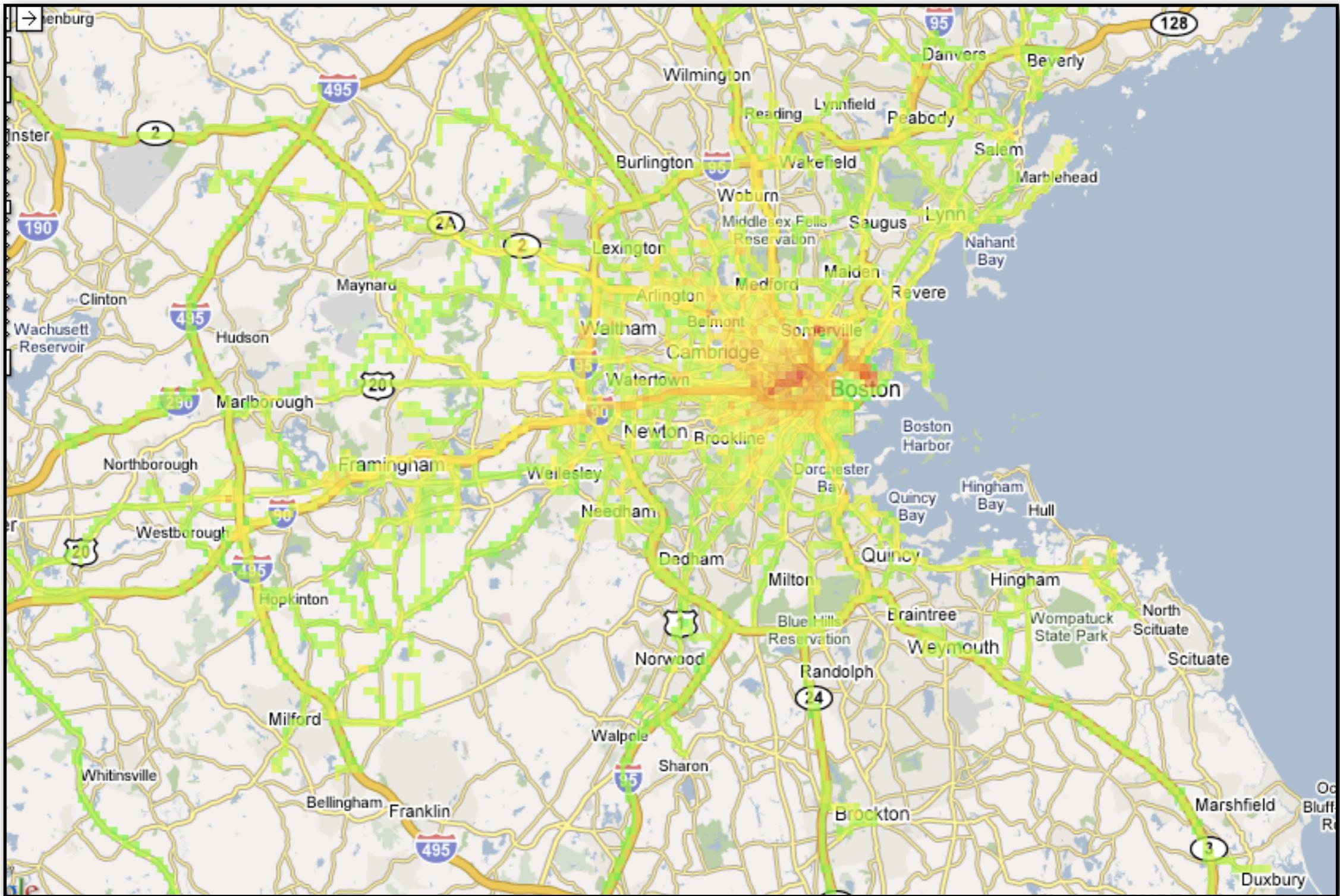
$ax$ : on road plane, perpendicular to road

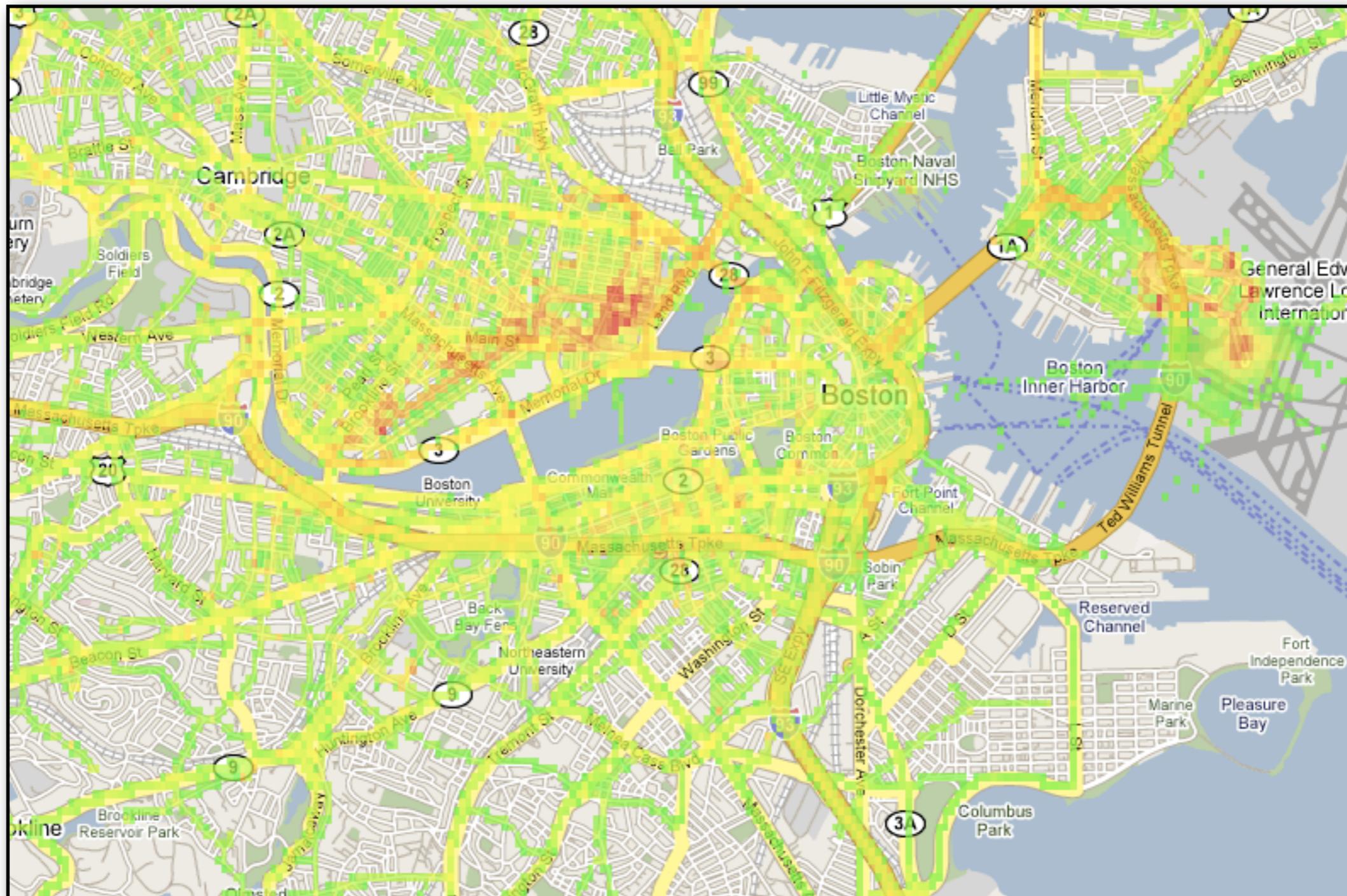
# experimental platform

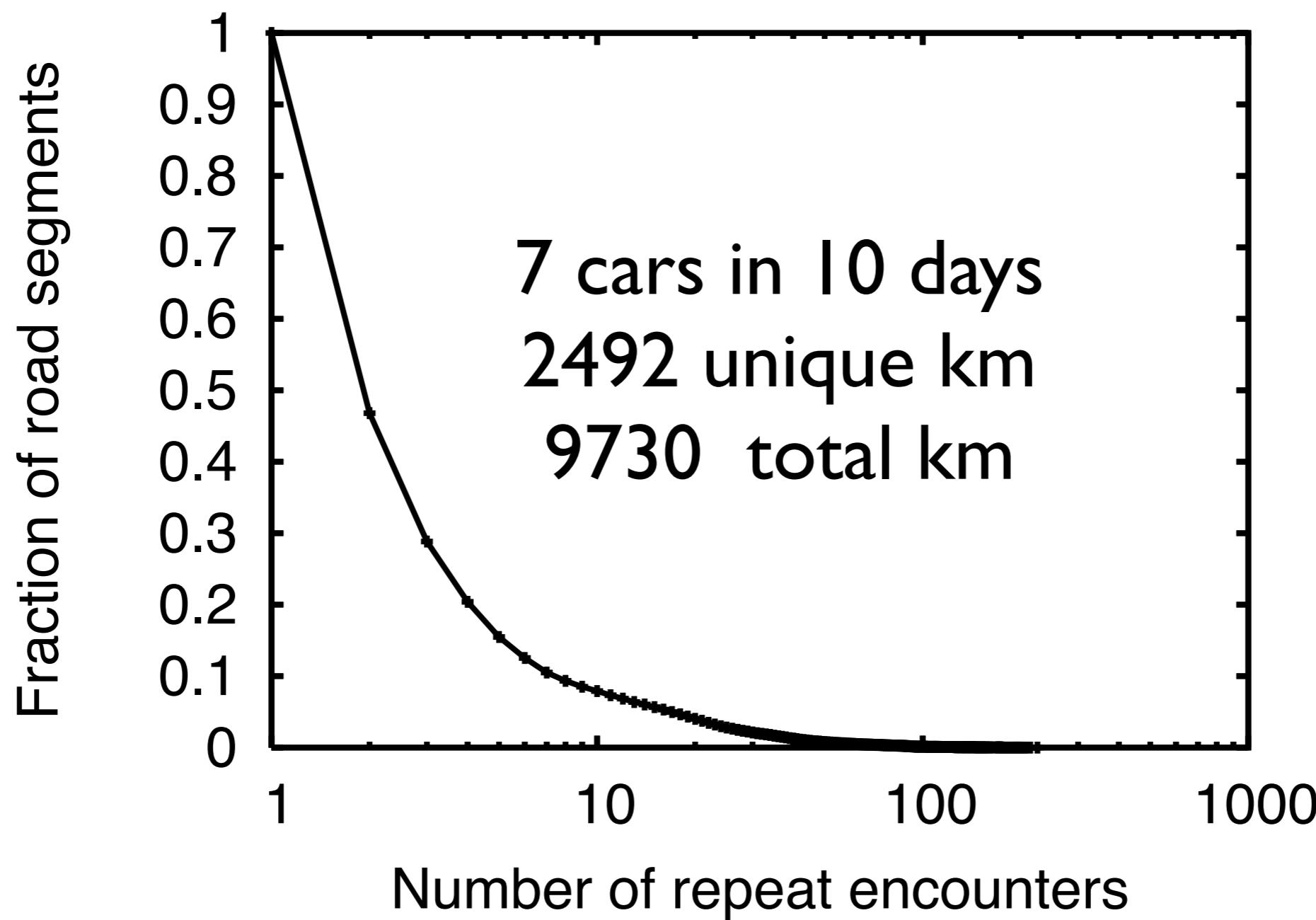
- 7 Boston/Cambridge taxis
- small computer in glove box
- 380 Hz 3-axis accelerometer
- 802.11a/b/g wireless interface
- GPS receiver on roof
- <time,location,heading,  
speed,ax,ay,az>



# wide-area sensing

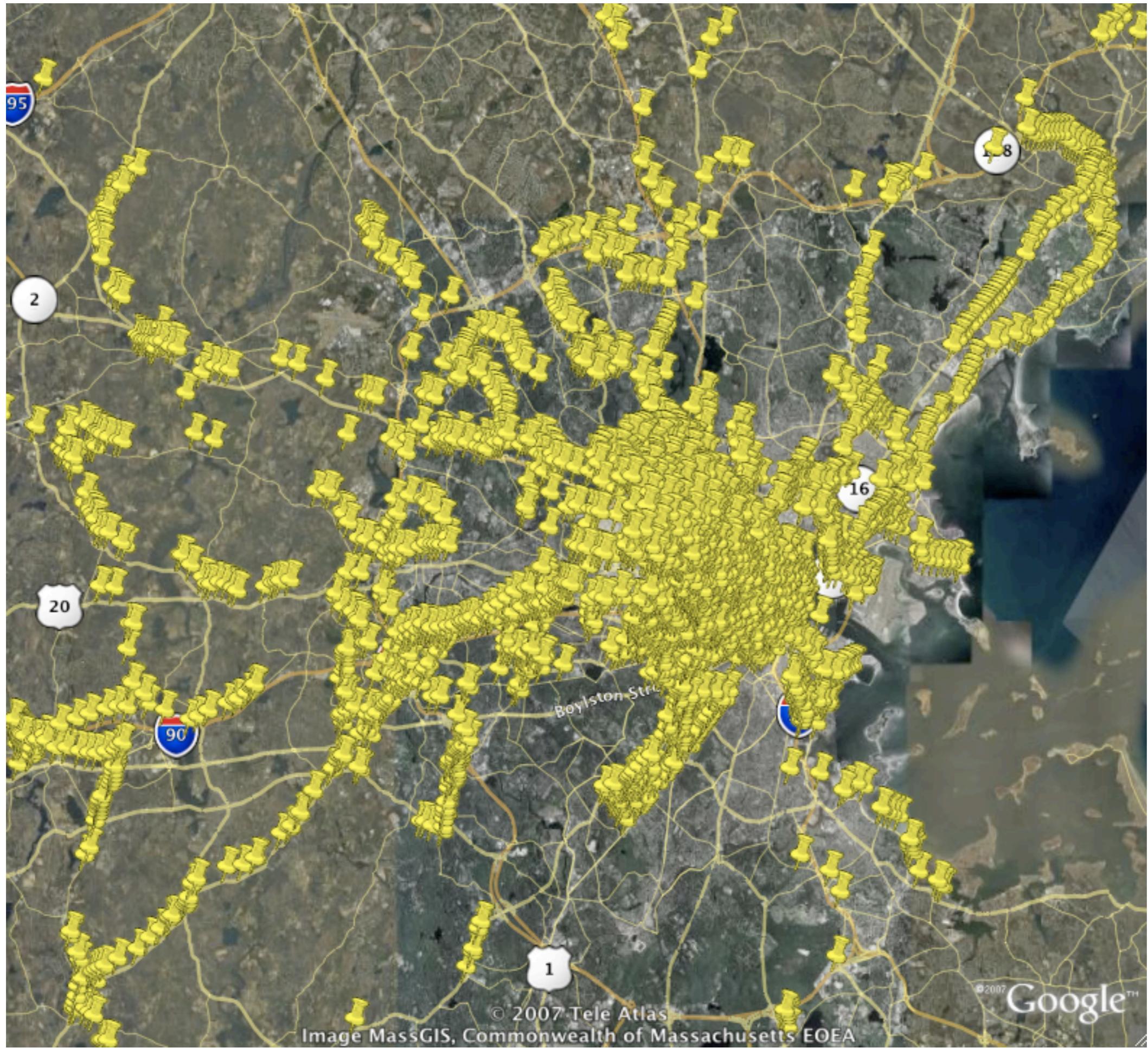






# open WiFi connectivity

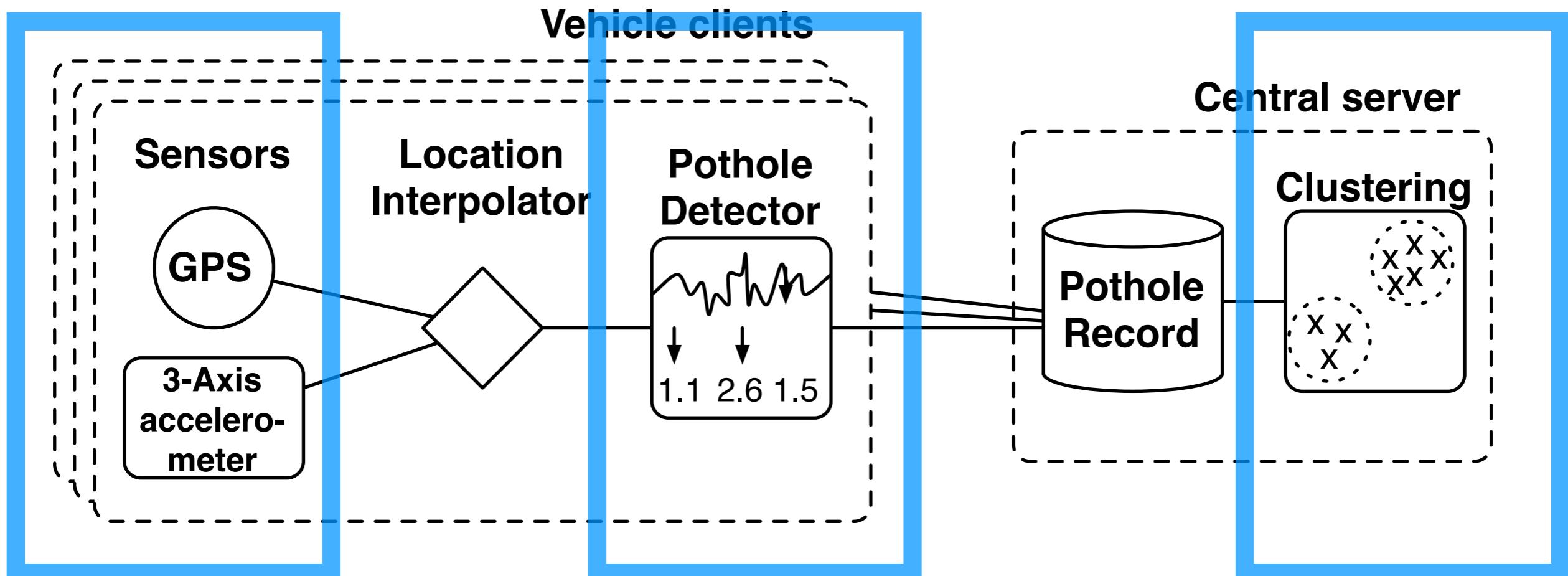




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# P2 architecture



# sensor placement

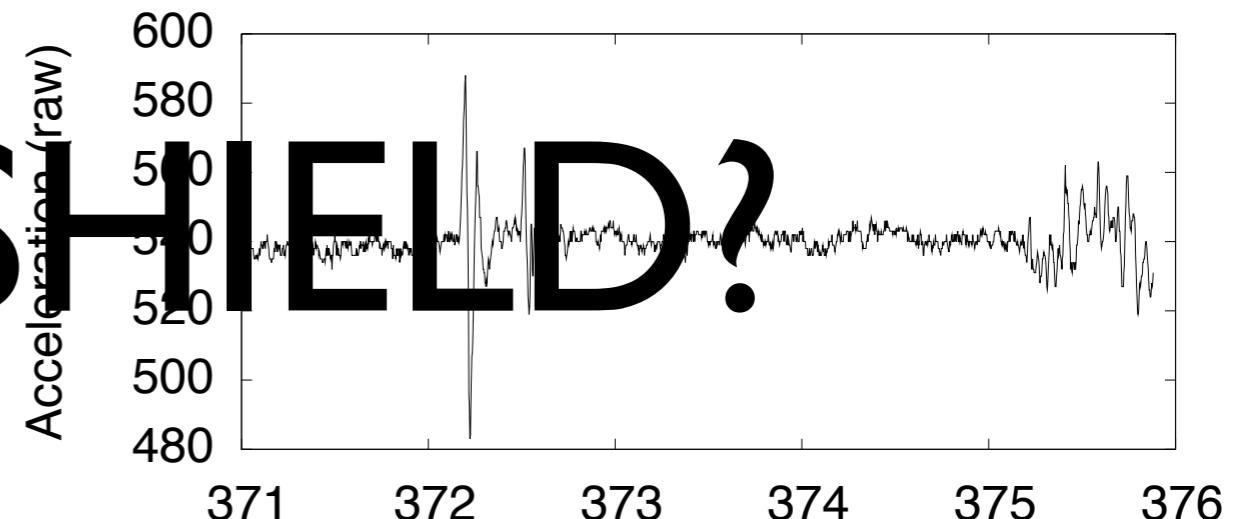


try to stay  
inside vehicle

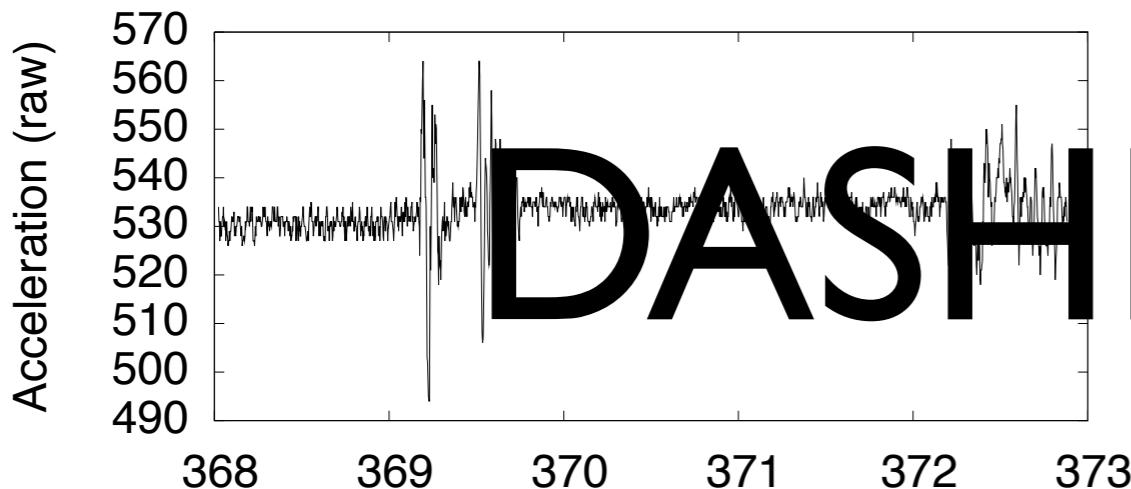
- highly accurate
- difficult mounting
- extreme exposure

- very clean signal
- ‘gold standard’
- difficult to mount

**WINDSHIELD?**



Attached to Dashboard



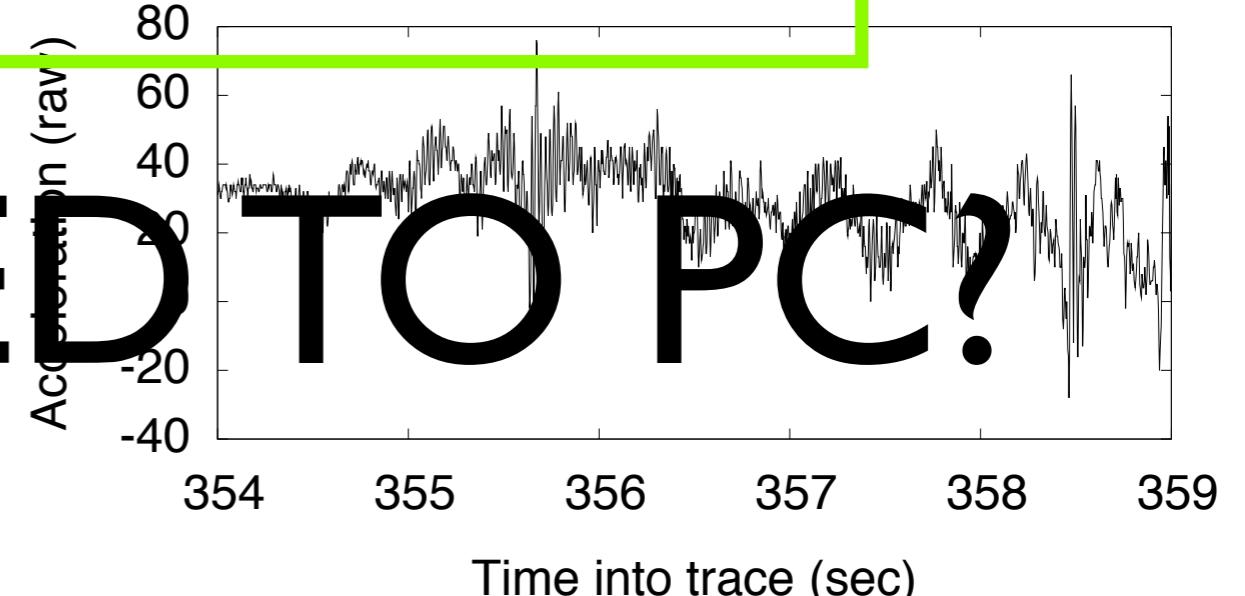
Time into trace (sec)

- good signal
- easy to mount
- out of the way

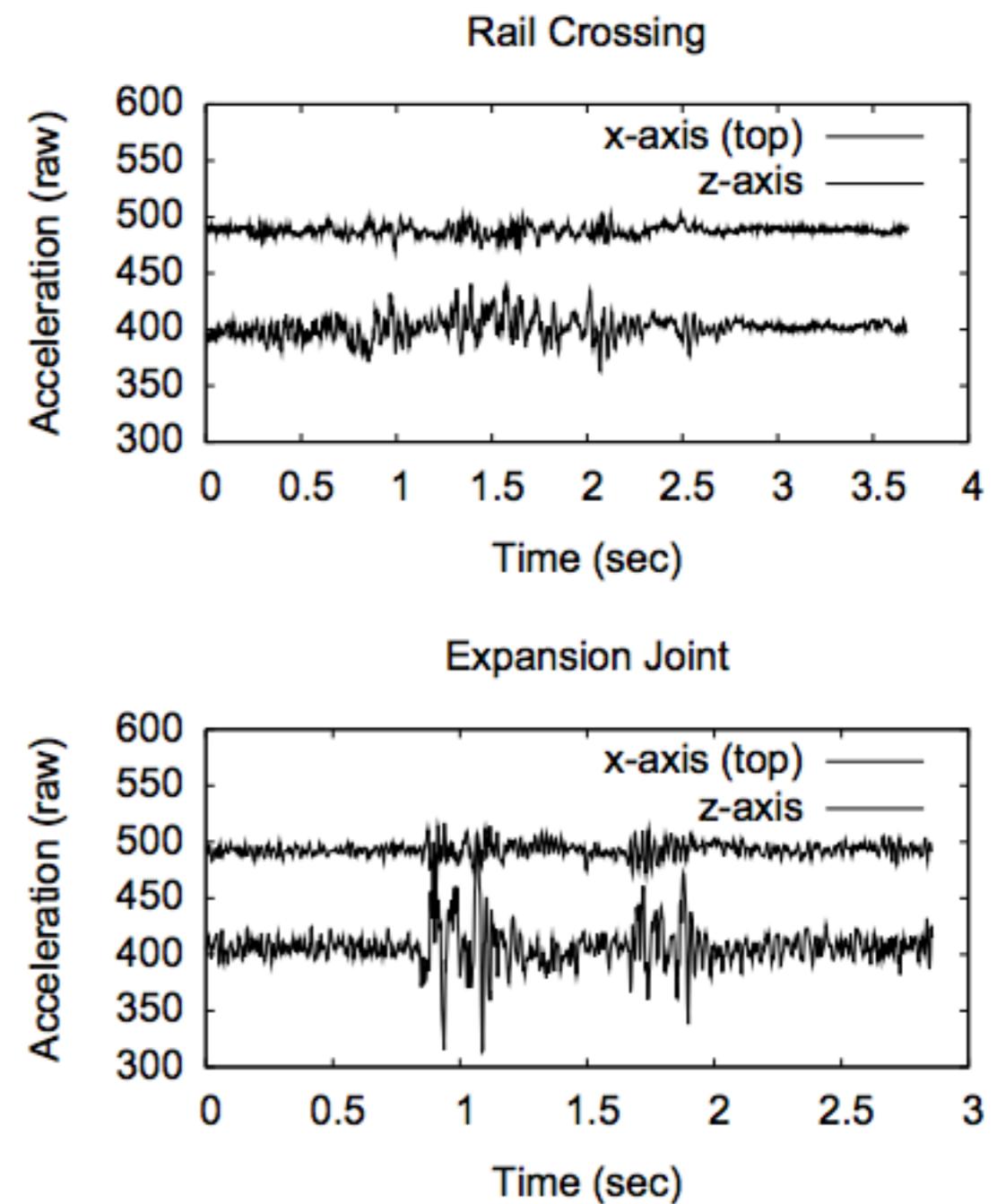
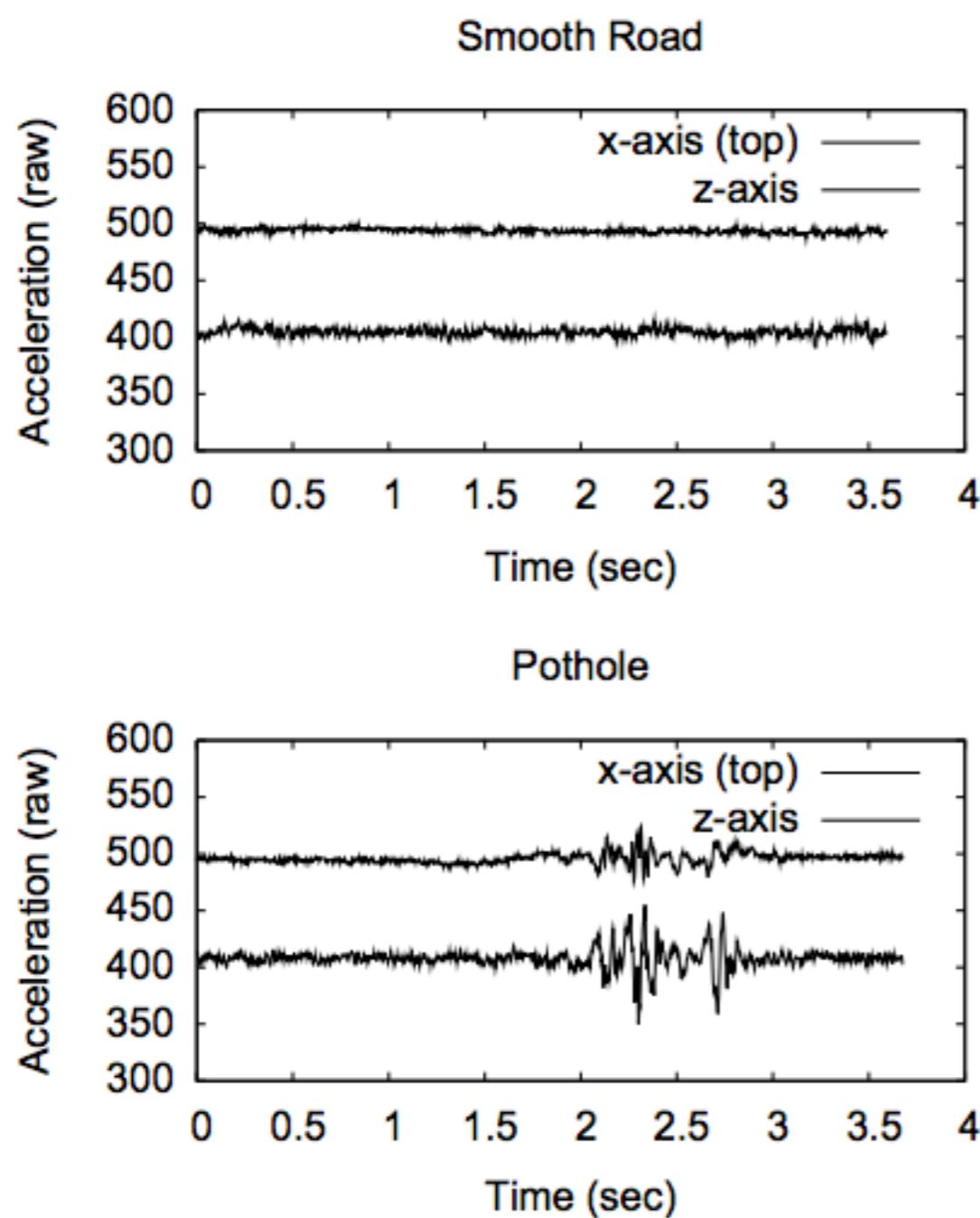
**DASHBOARD?**

- very poor signal
- no mounting necessary

**ATTACHED TO PC?**

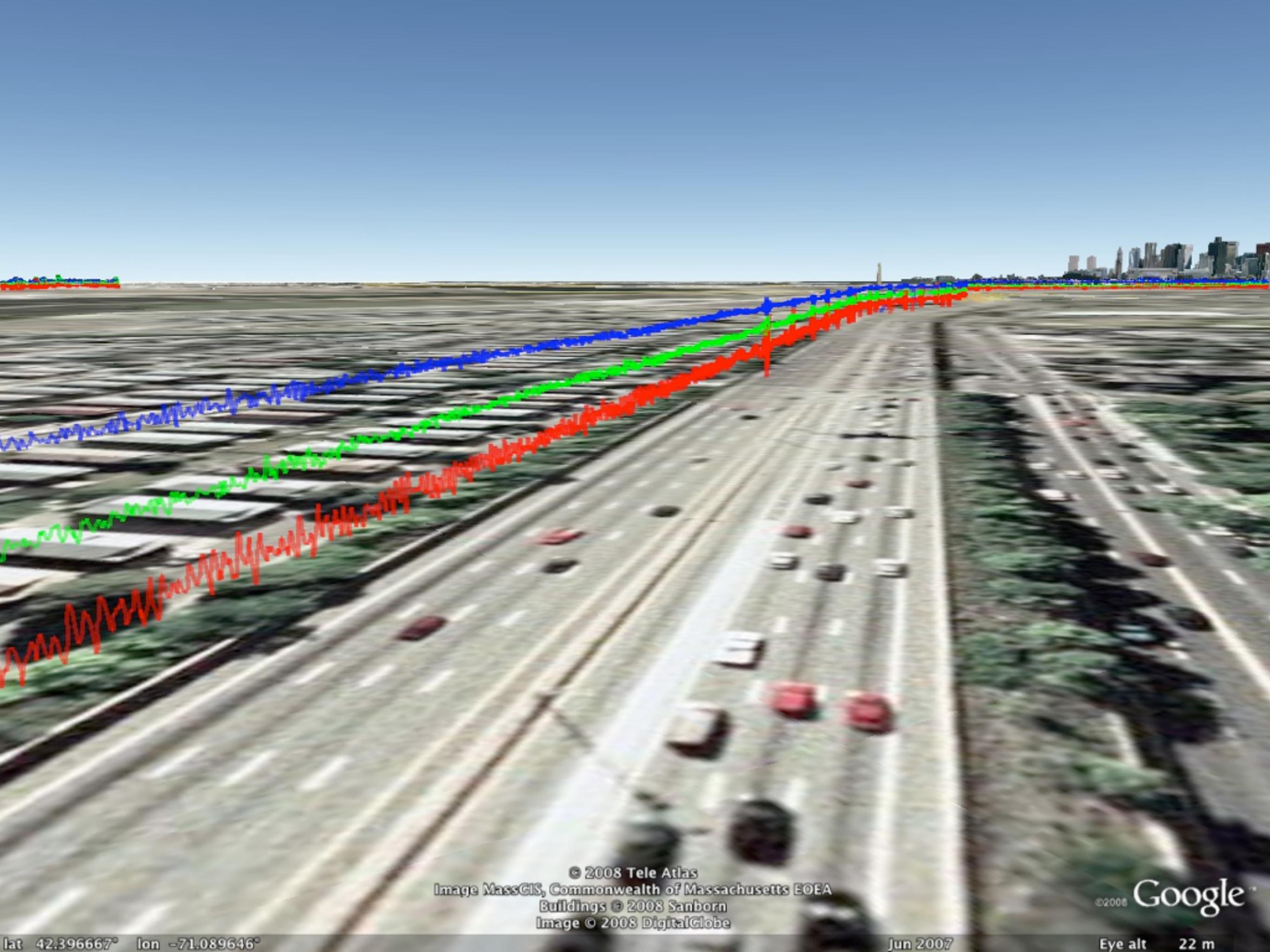


# challenge: “pothole” v. “not pothole”



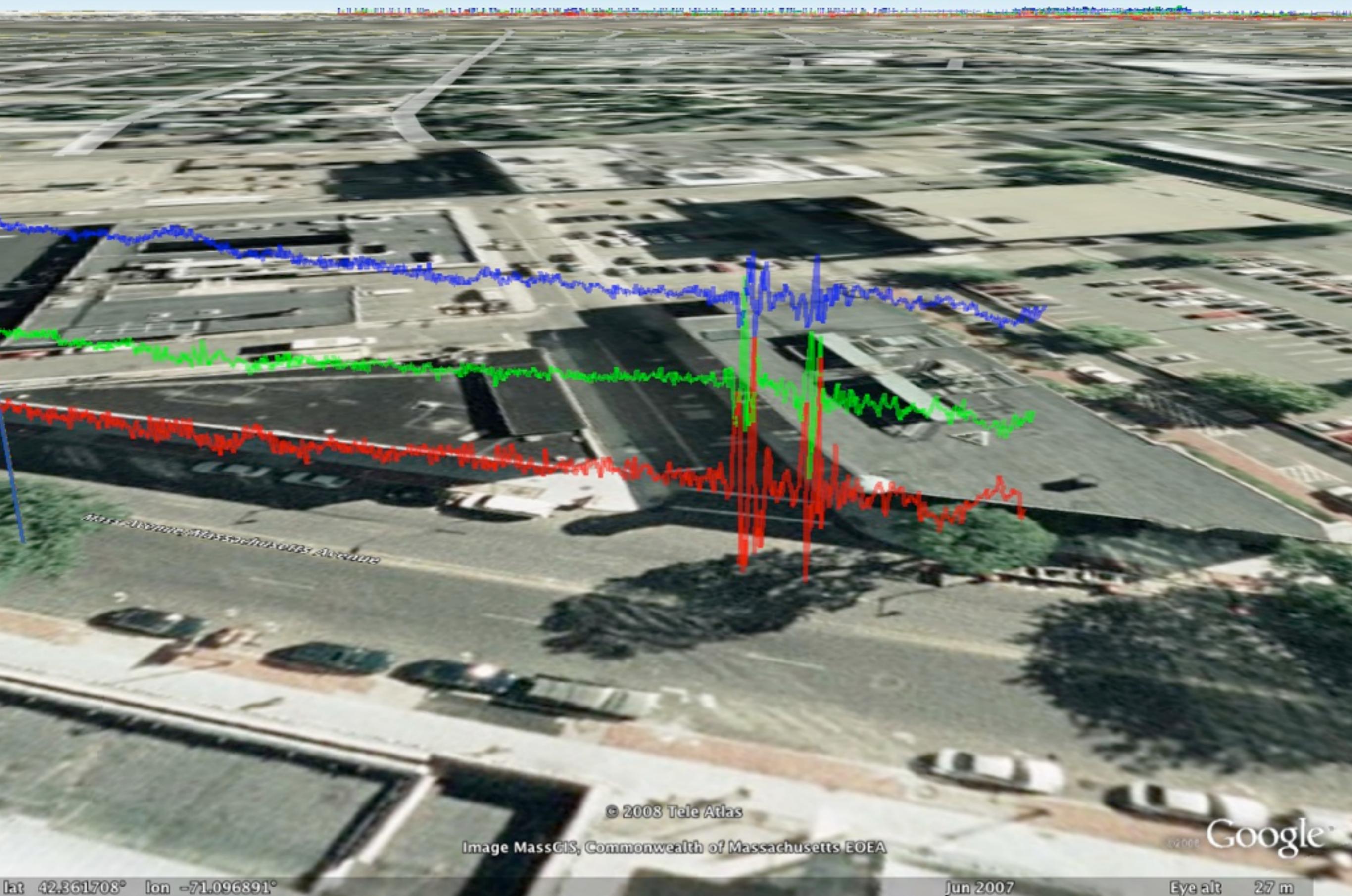
# pothole v. not pothole





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Image © 2008 DigitalGlobe

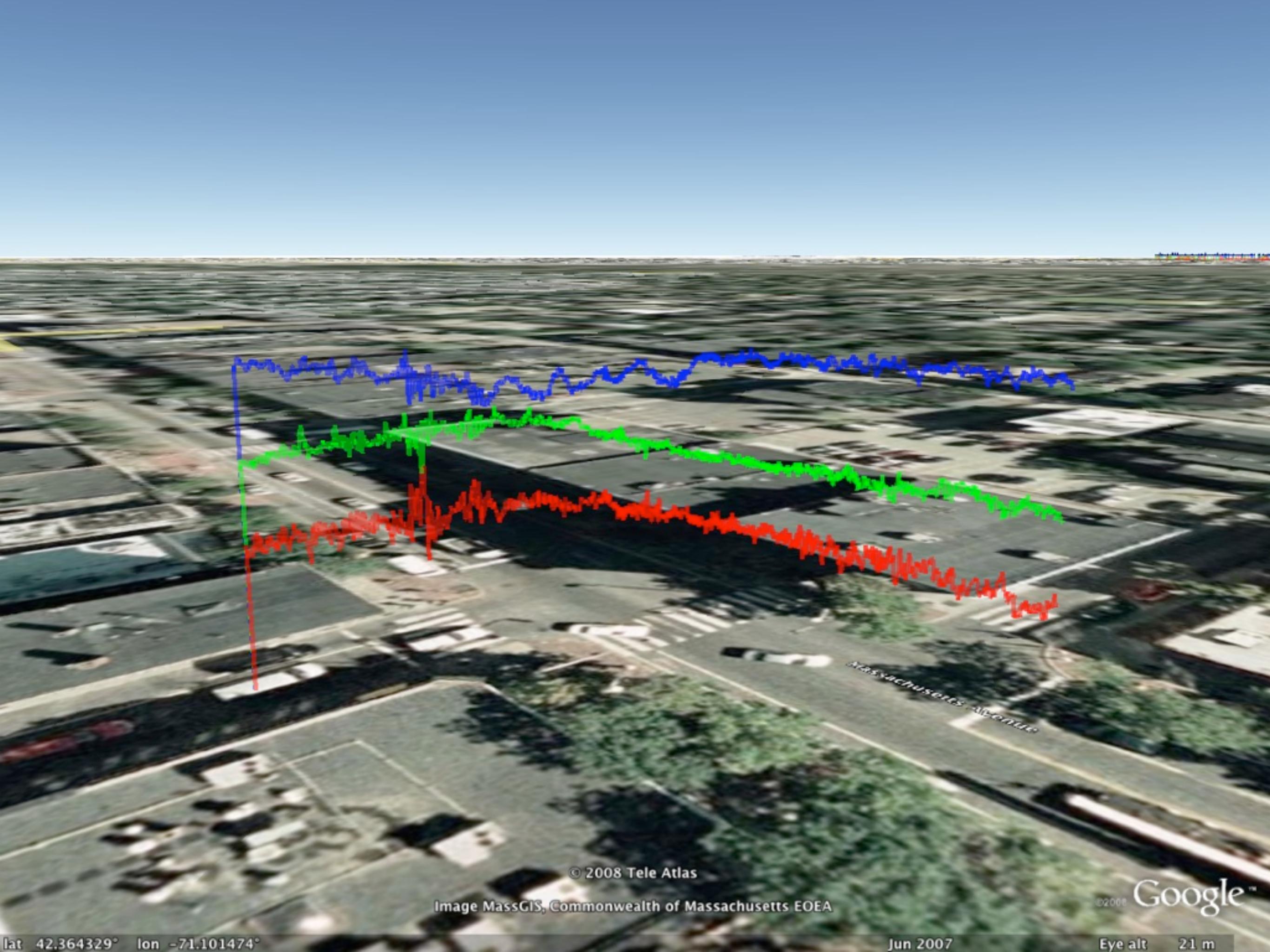
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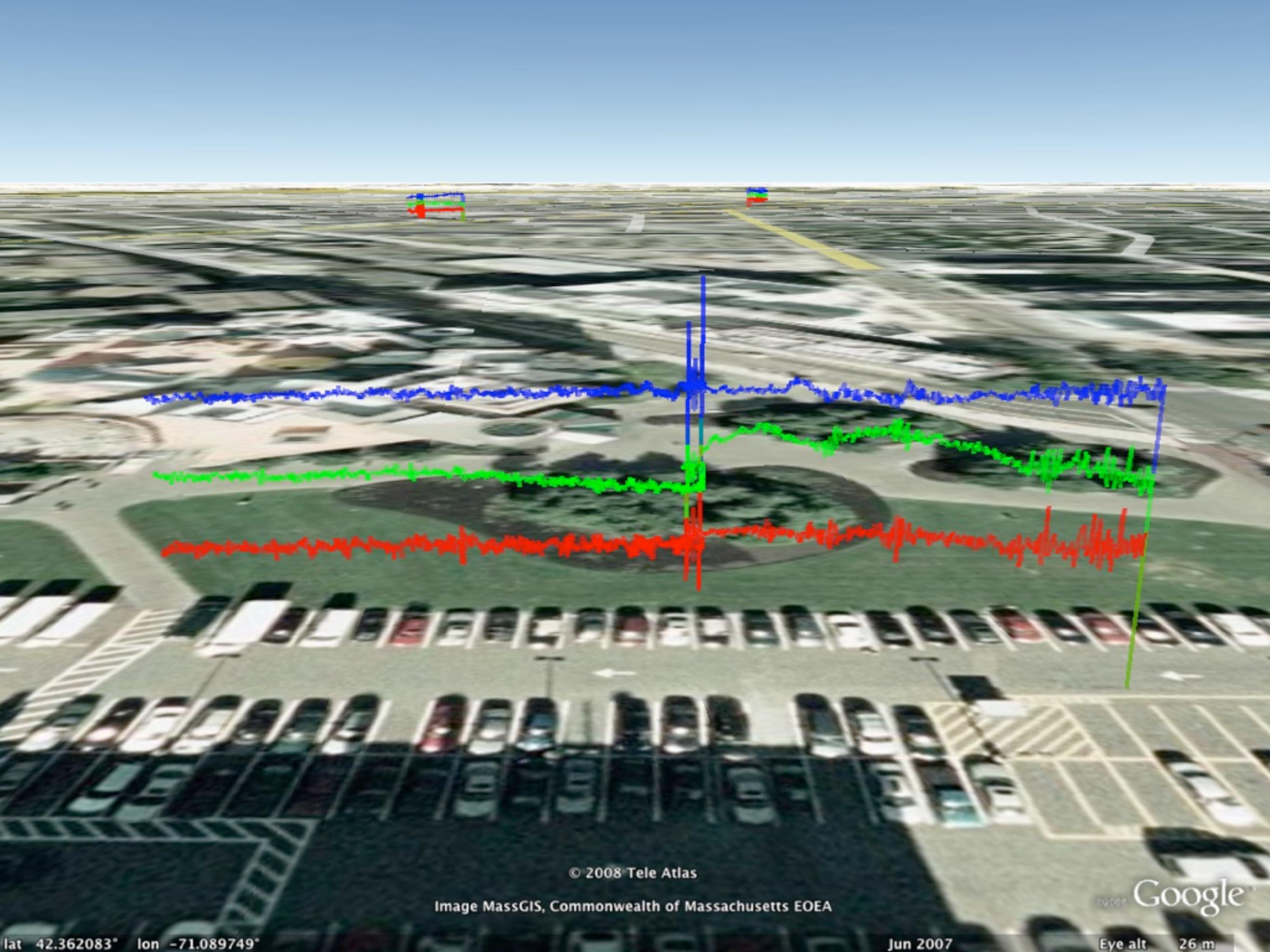
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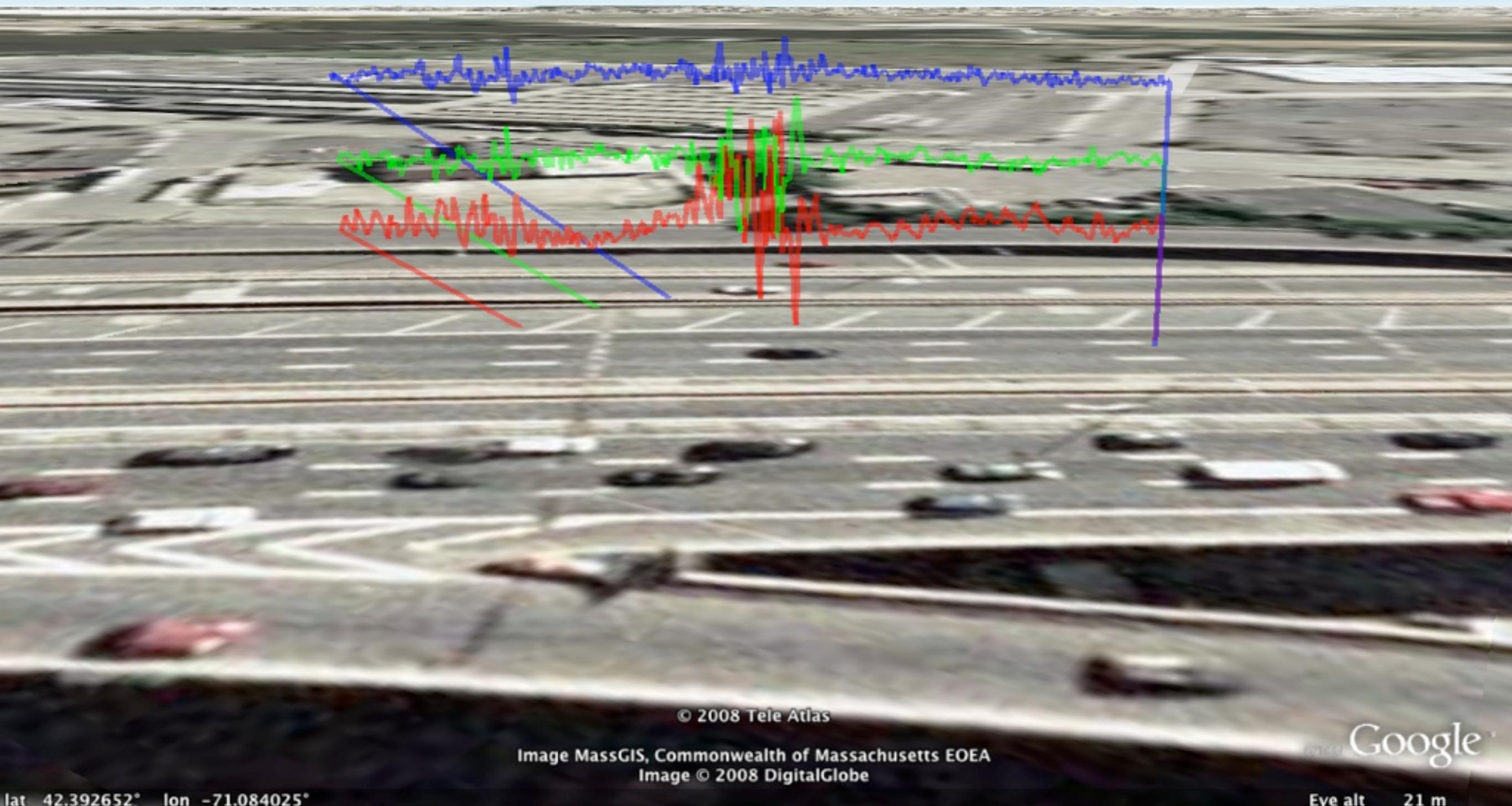
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Google

lat 42.362083° lon -71.089749°

Jun 2007

Eye alt 26 m



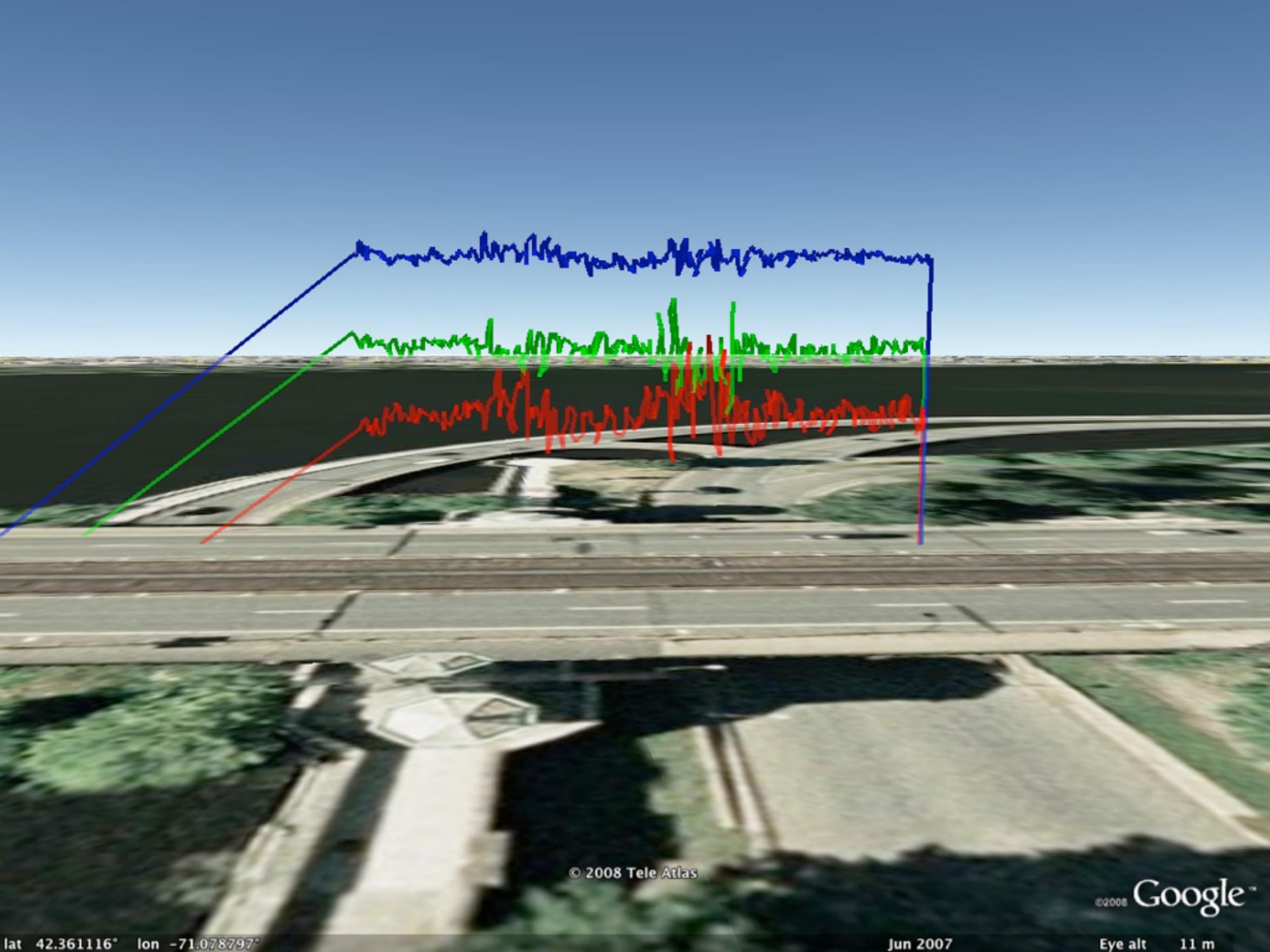
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Google

lat 42.392652° lon -71.084025°

Eye alt 21 m



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lat 42.361116° lon -71.078797°

Jun 2007

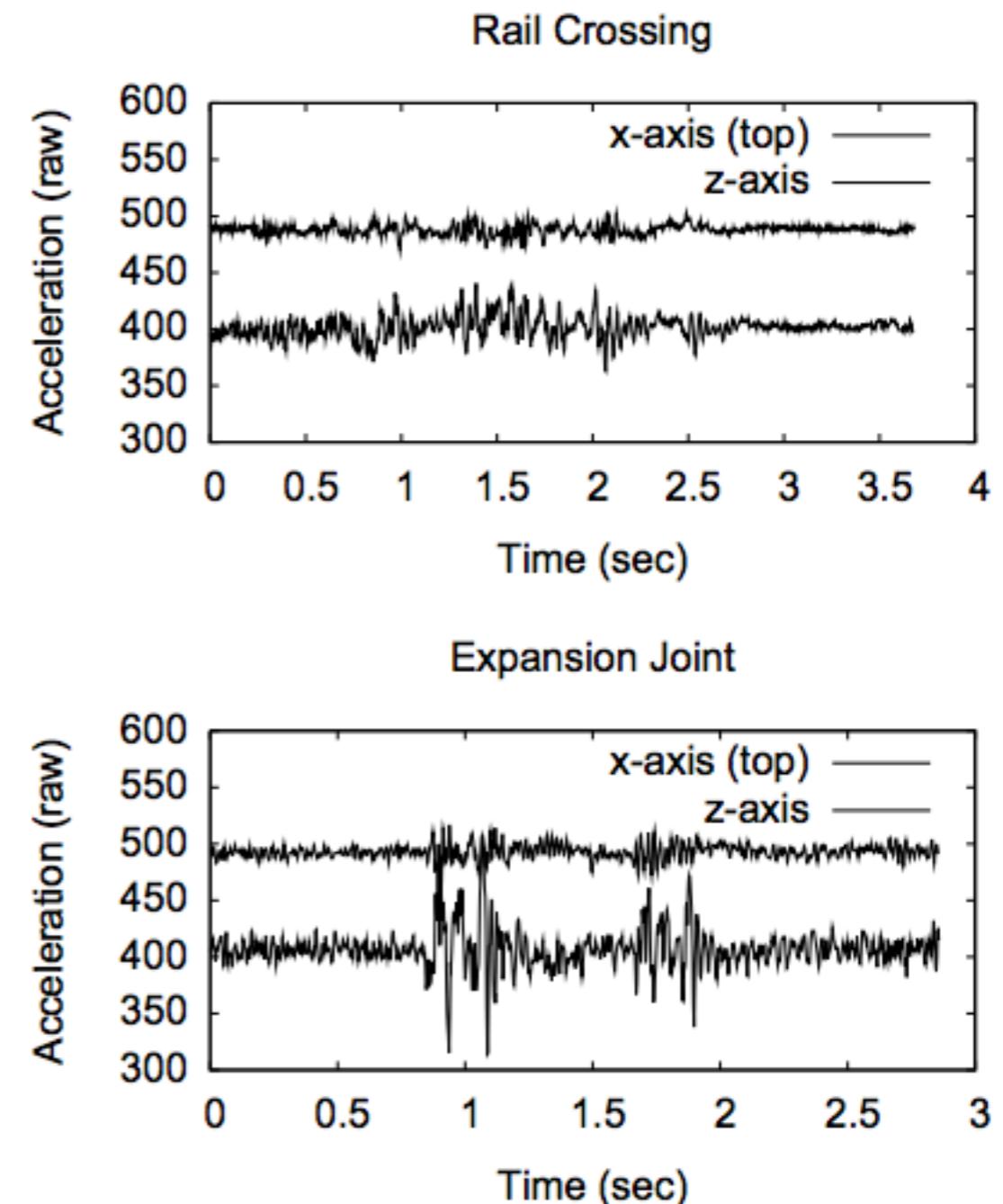
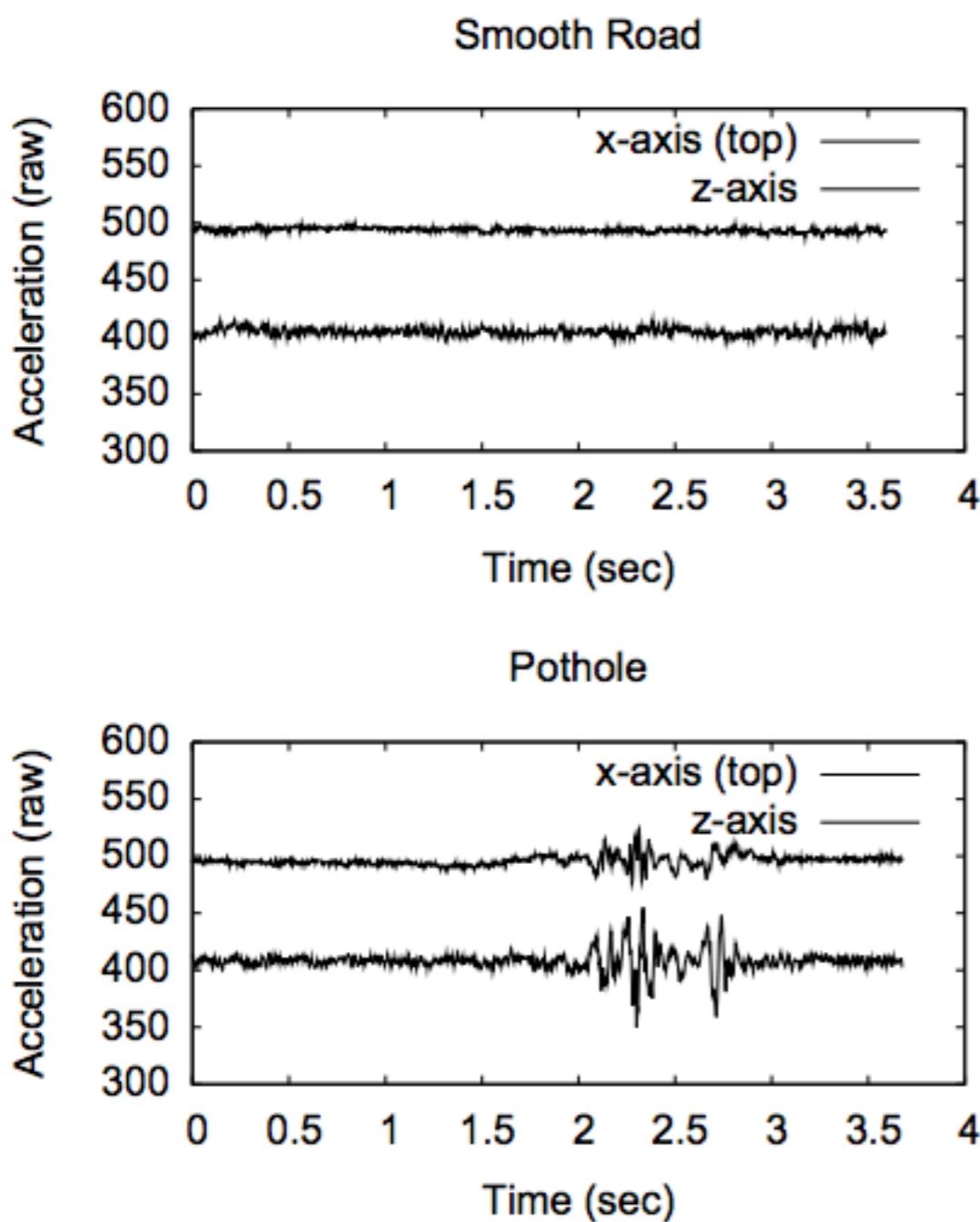
Eye alt 11 m

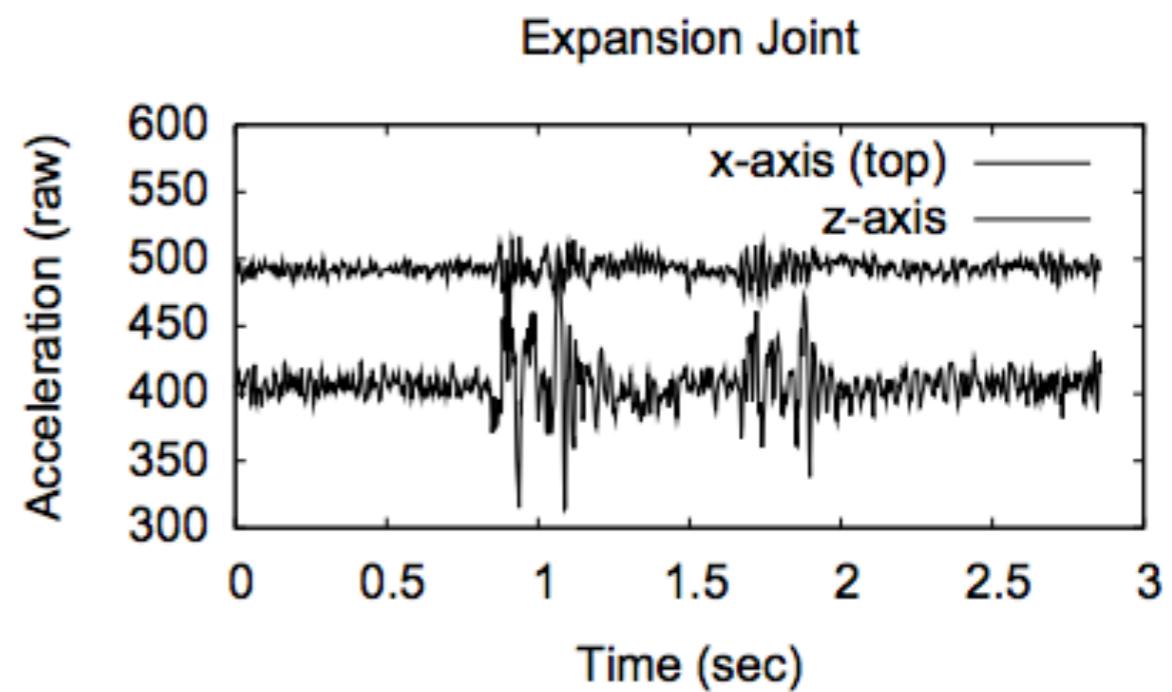
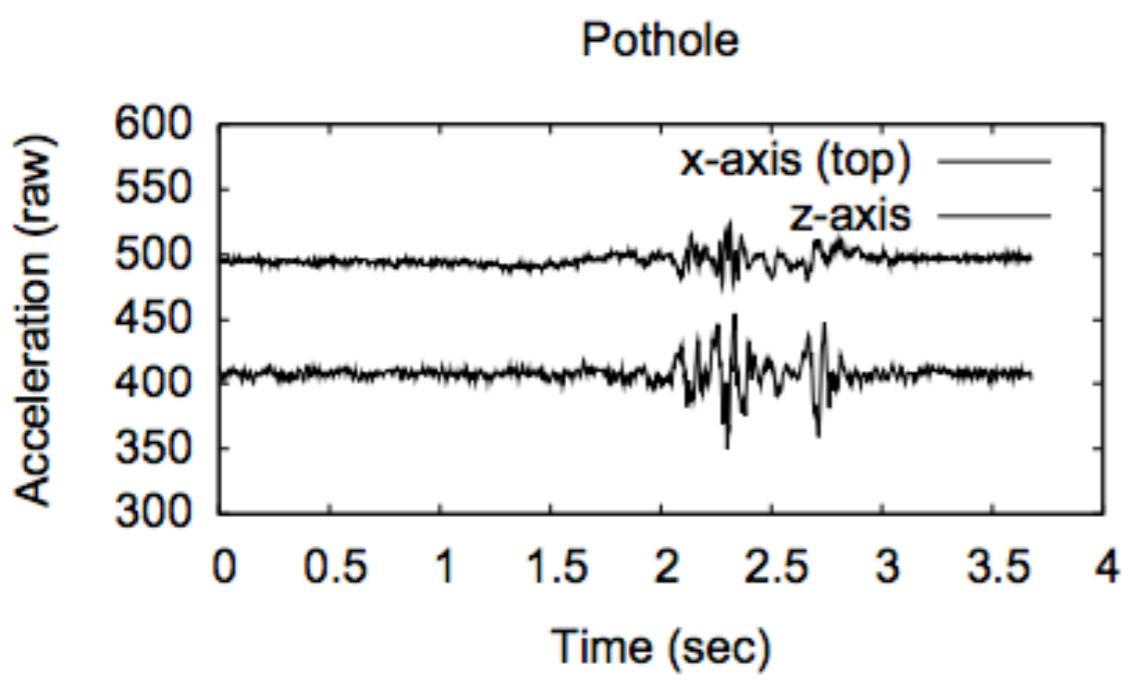
# P<sup>2</sup> detector

256-sample  
windows →

need  
threshold  
parameters

Events usually of much shorter duration than 256 samples





# 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
<b>Smooth road (SM)</b>	64	23%
<b>Potholes (PH)</b>	63	23%
<b>Manholes (MH)</b>	59	21%
<b>Railroad Crossing (RC)</b>	18	6%
<b>Crosswalk/Exp. Joint (CWEJ)</b>	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

$$s(t) = corr - incorr^2$$

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

# detector performance

<b>Class</b>	<b>before</b>	<b>after</b>	After training on loosely labeled data
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



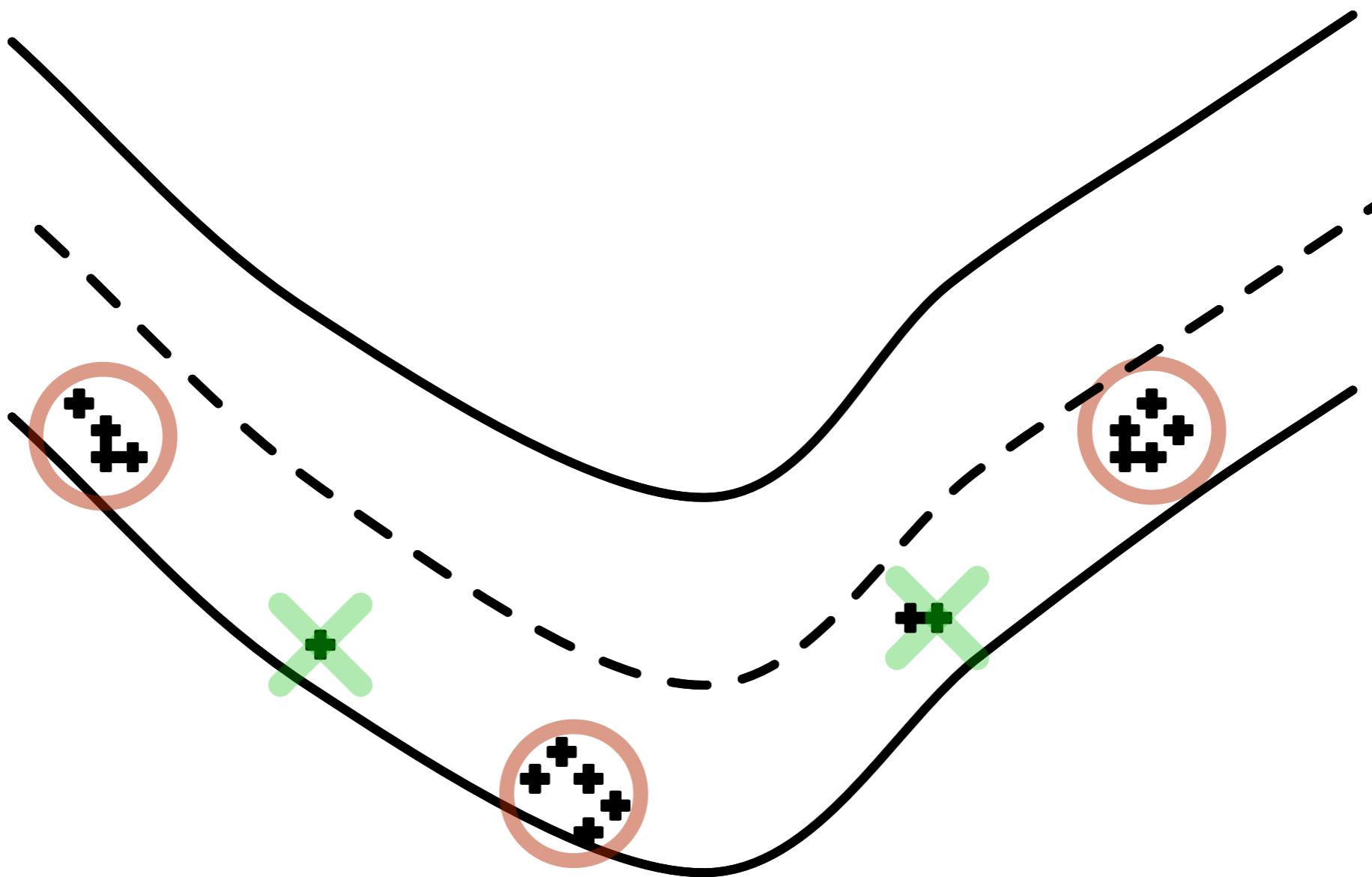
Note: Actual false positive rate is not 7.6%  
Why?

# 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%



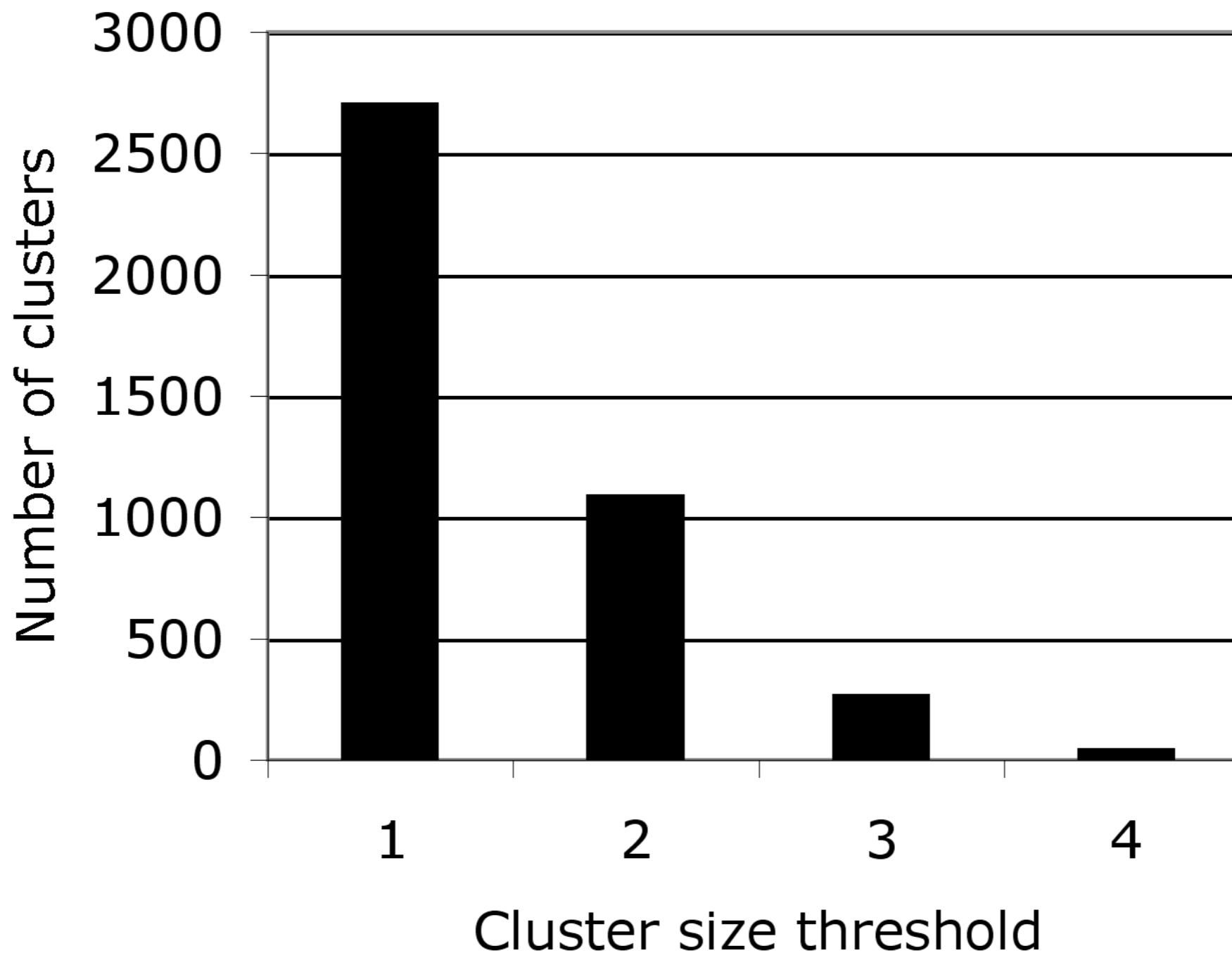
# clustering

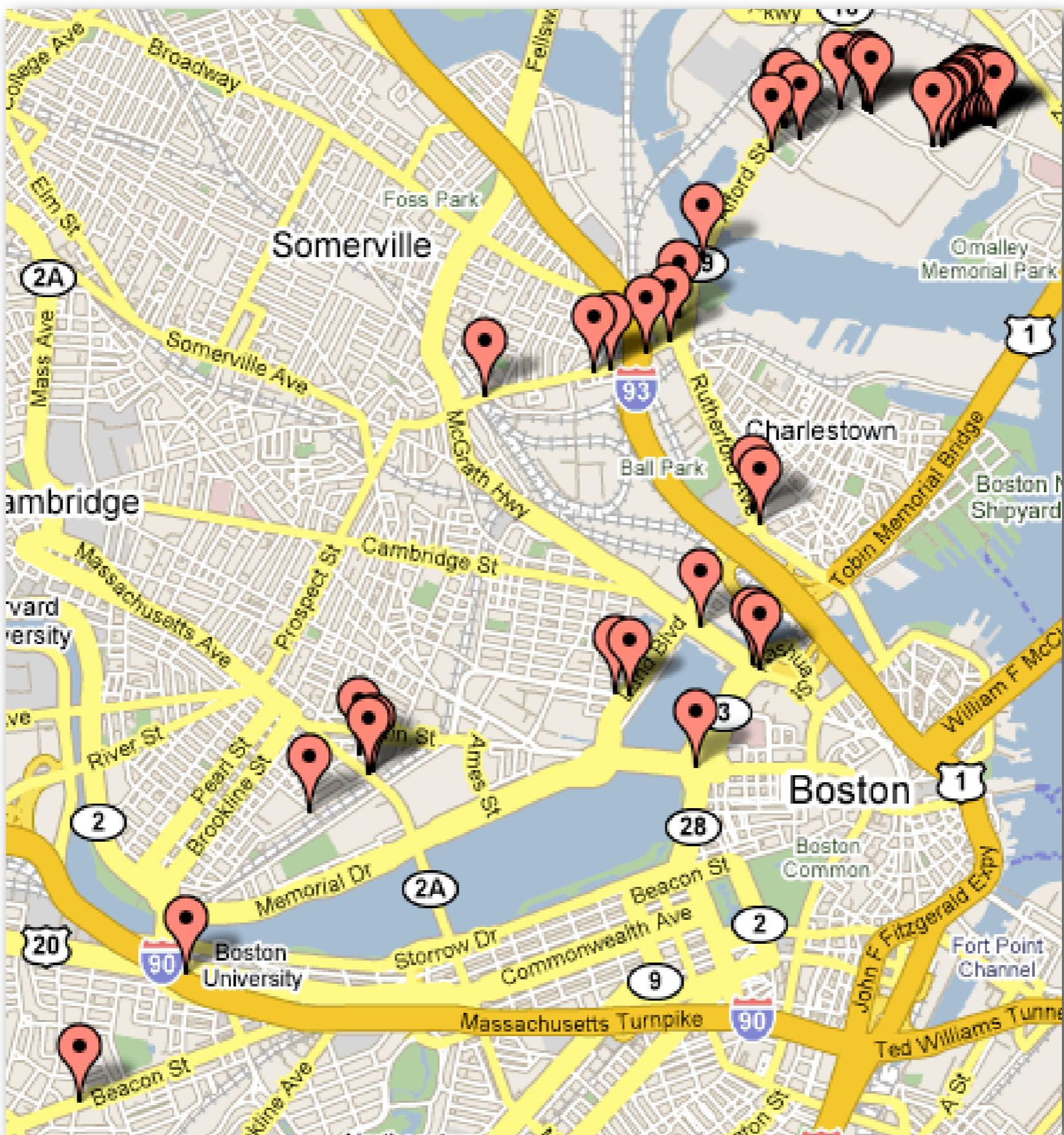


# experiments

- 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

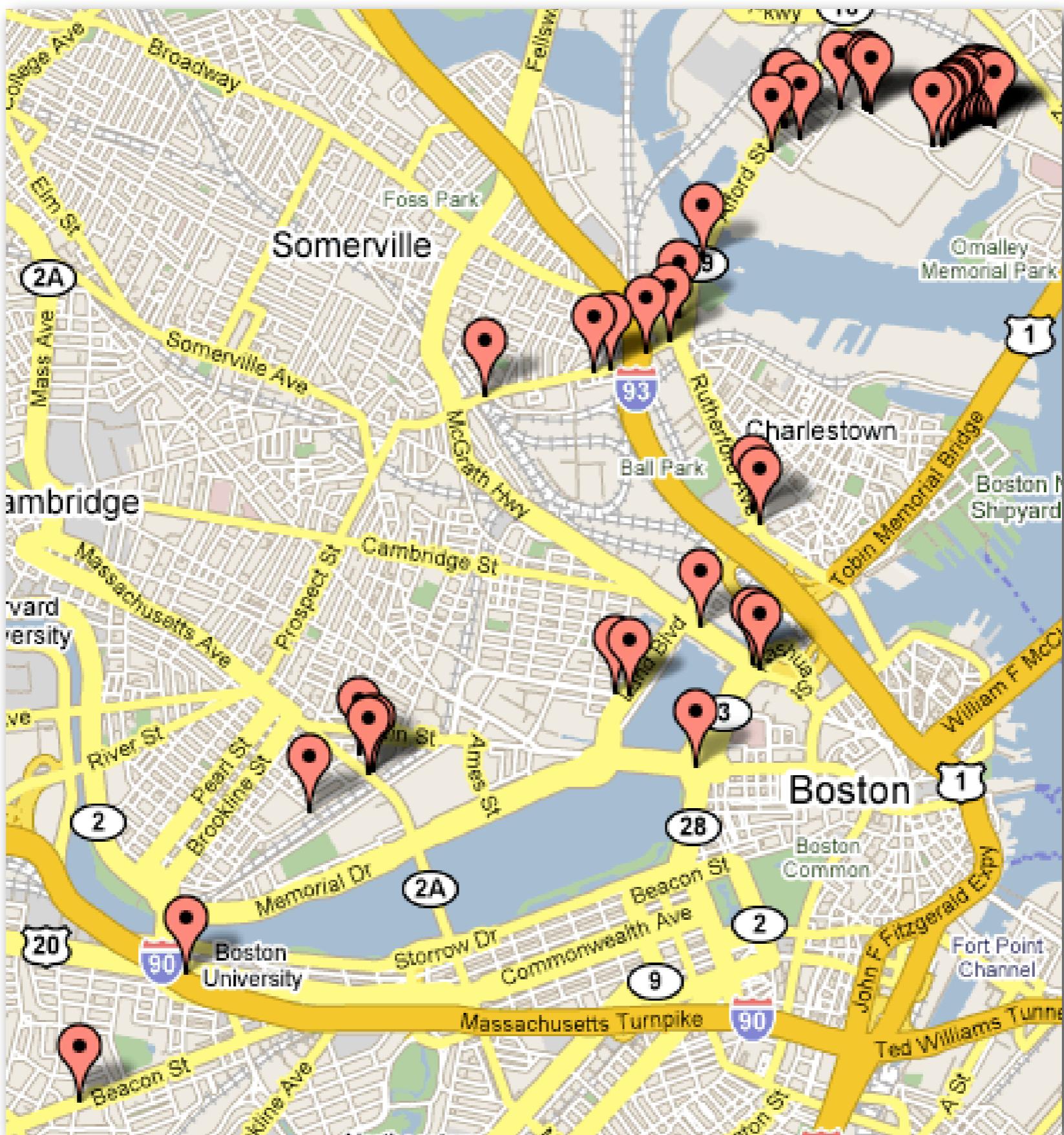


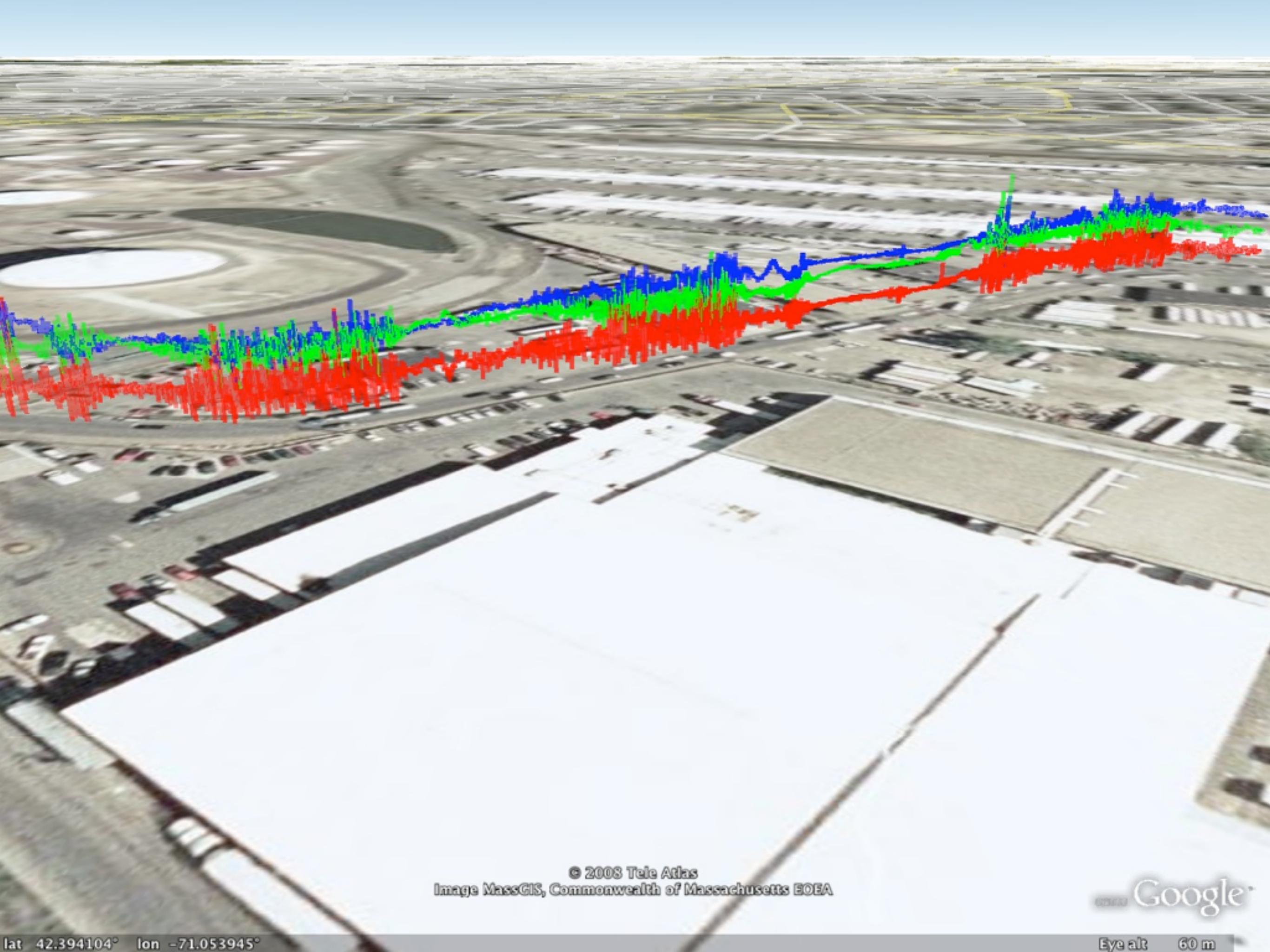


# 48 spot-checks

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







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# 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