

The Pothole Patrol

6.S062 Spring 2018

Lecture 8

3/6/2018

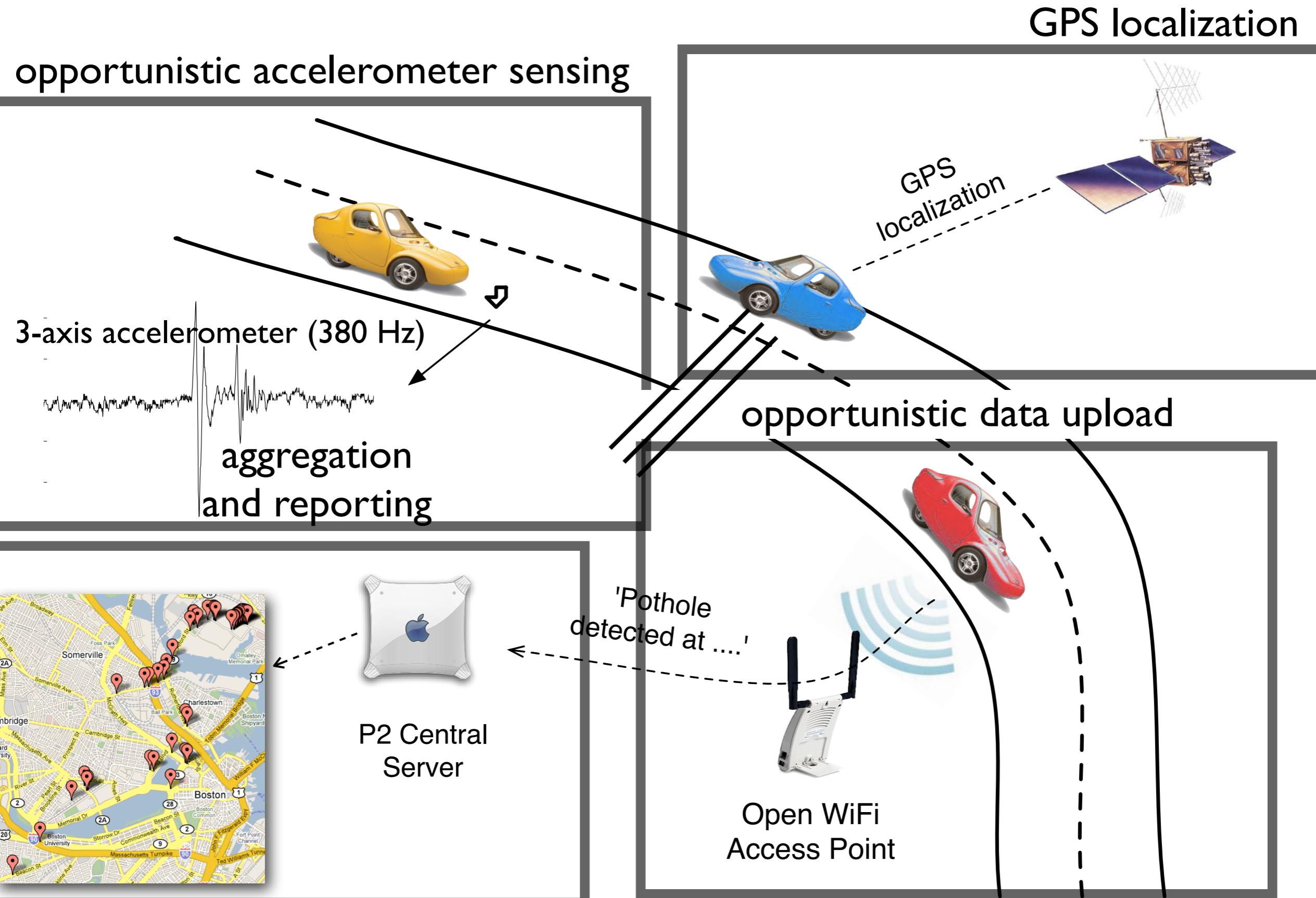
Balakrishnan & Adib

Based on Slides from Jakob Eriksson



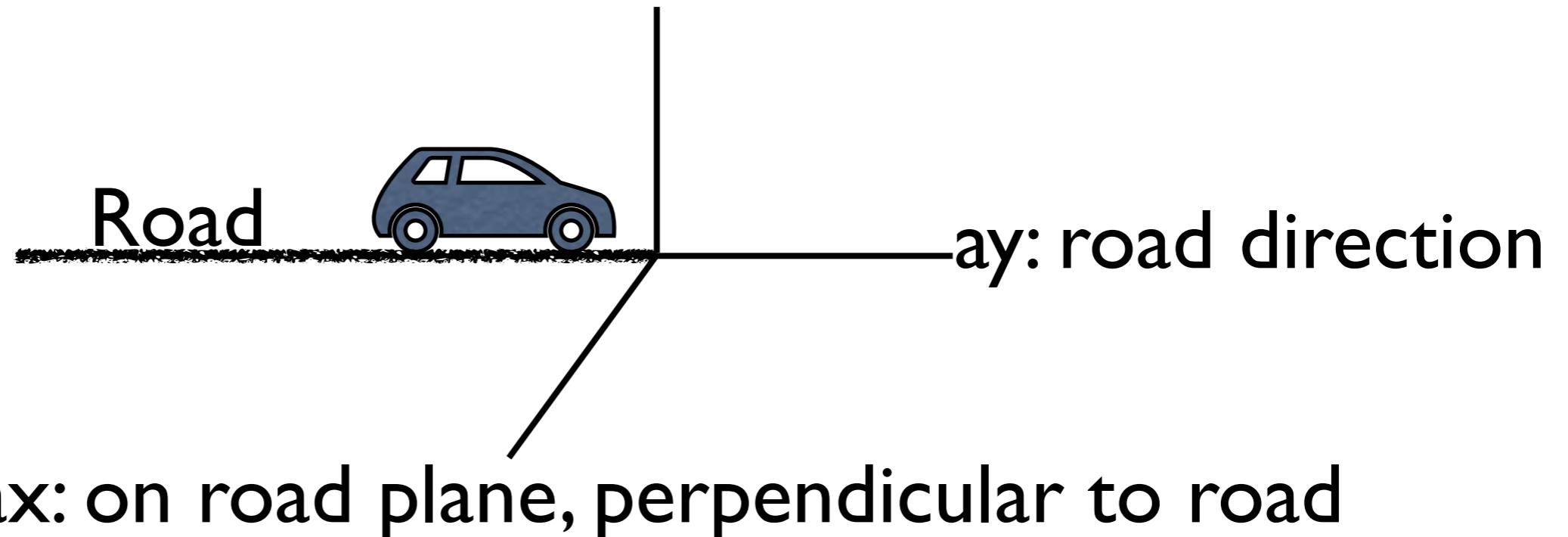
- road decay unavoidable, hard to predict
- current monitoring methods costly/ineffective

the Pothole Patrol



Acceleration vector

az : perpendicular to road plane



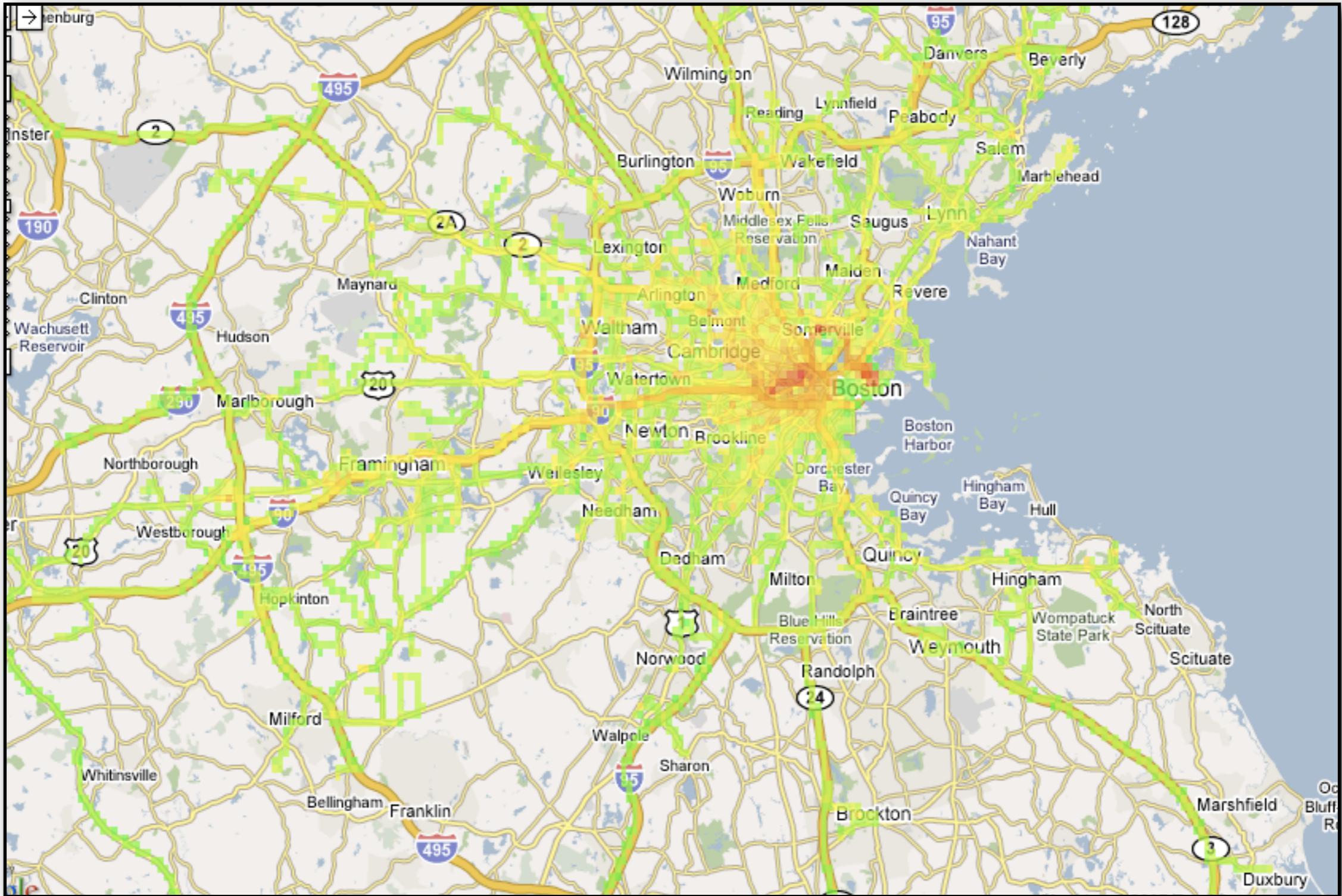
ax : on road plane, perpendicular to road

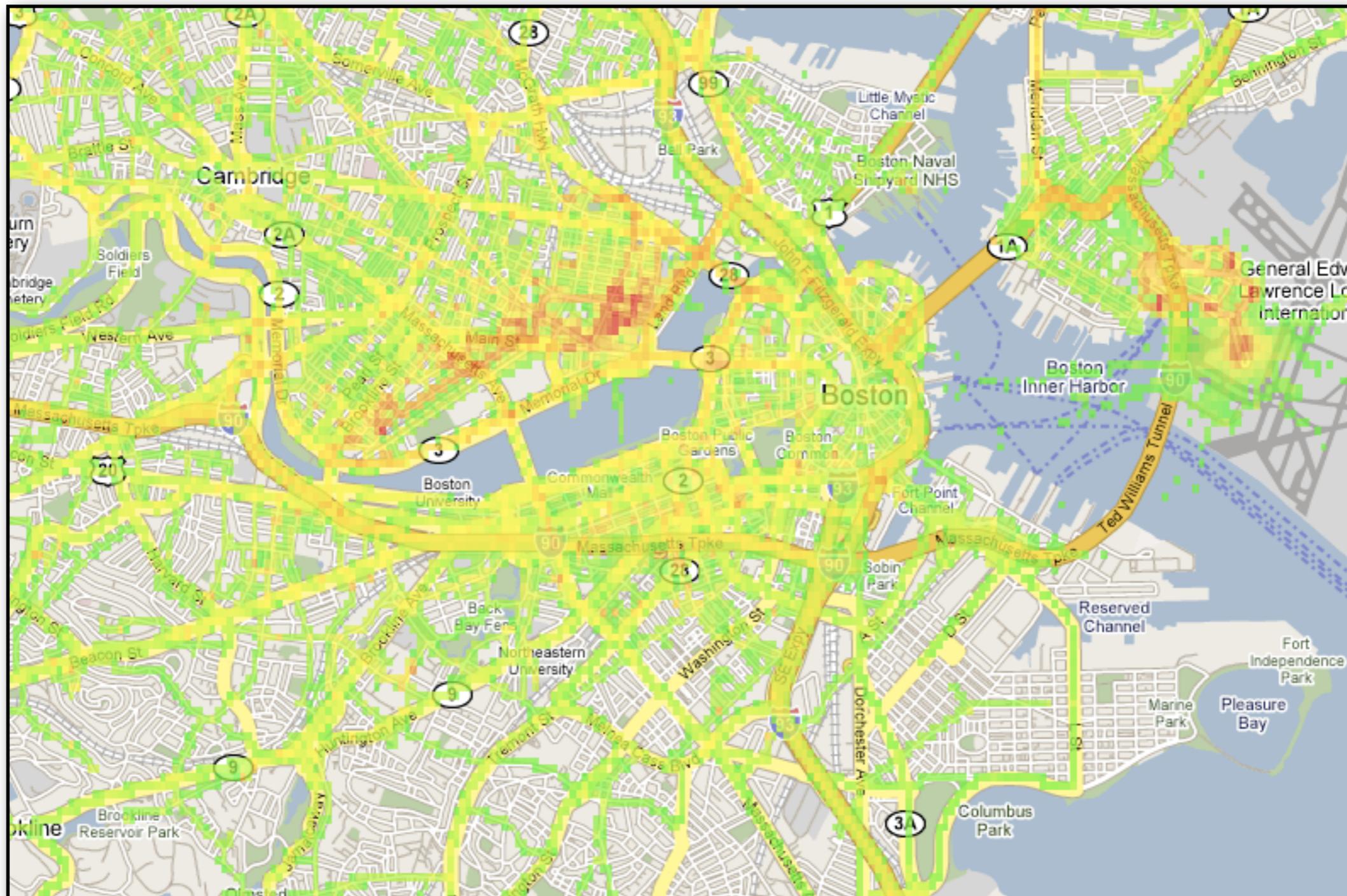
experimental platform

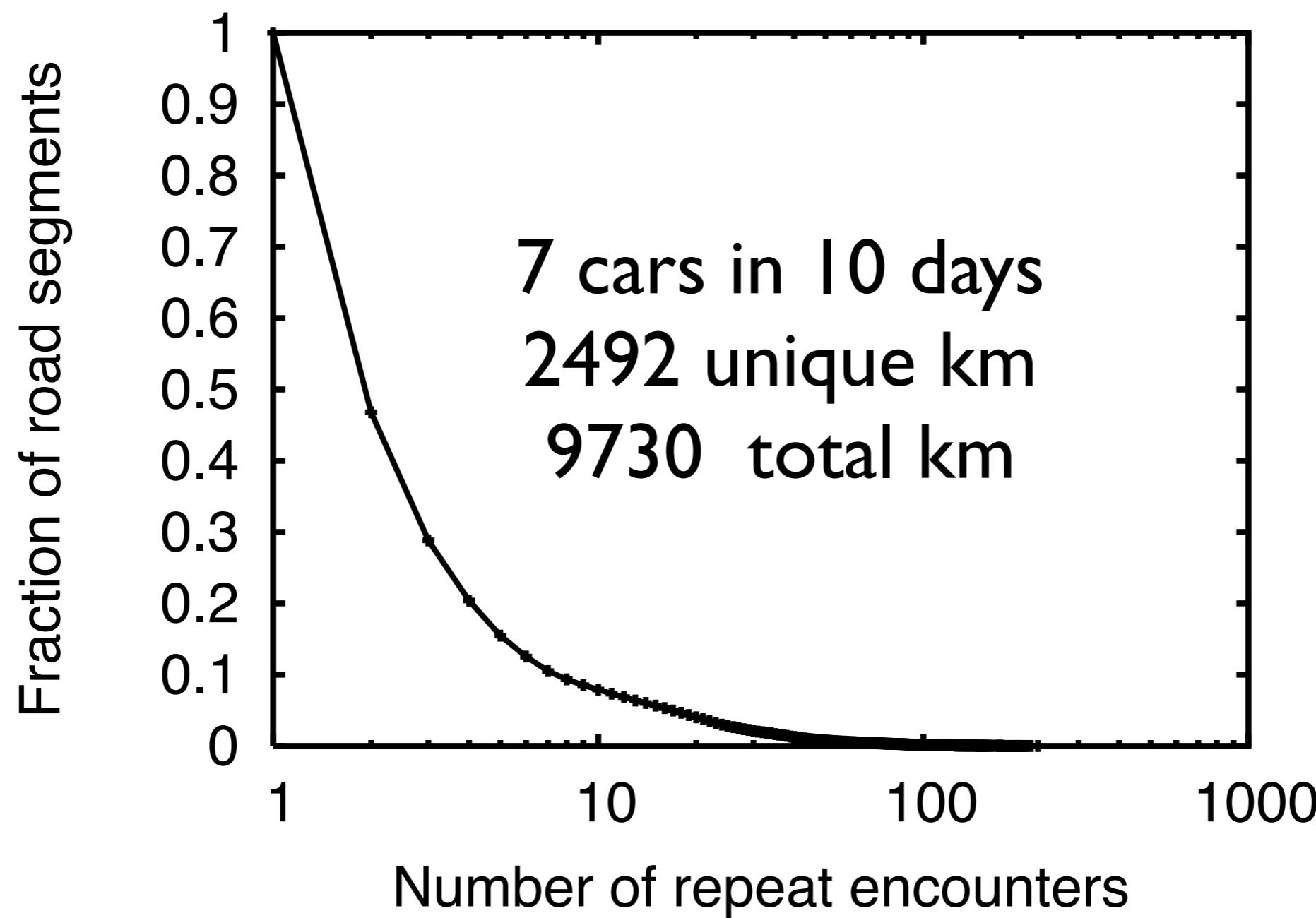
- 7 Boston/Cambridge taxis
- small computer in glove box
- 380 Hz 3-axis accelerometer
- 802.11a/b/g wireless interface
- GPS receiver on roof
- <time,location,heading,
speed,ax,ay,az>



wide-area sensing

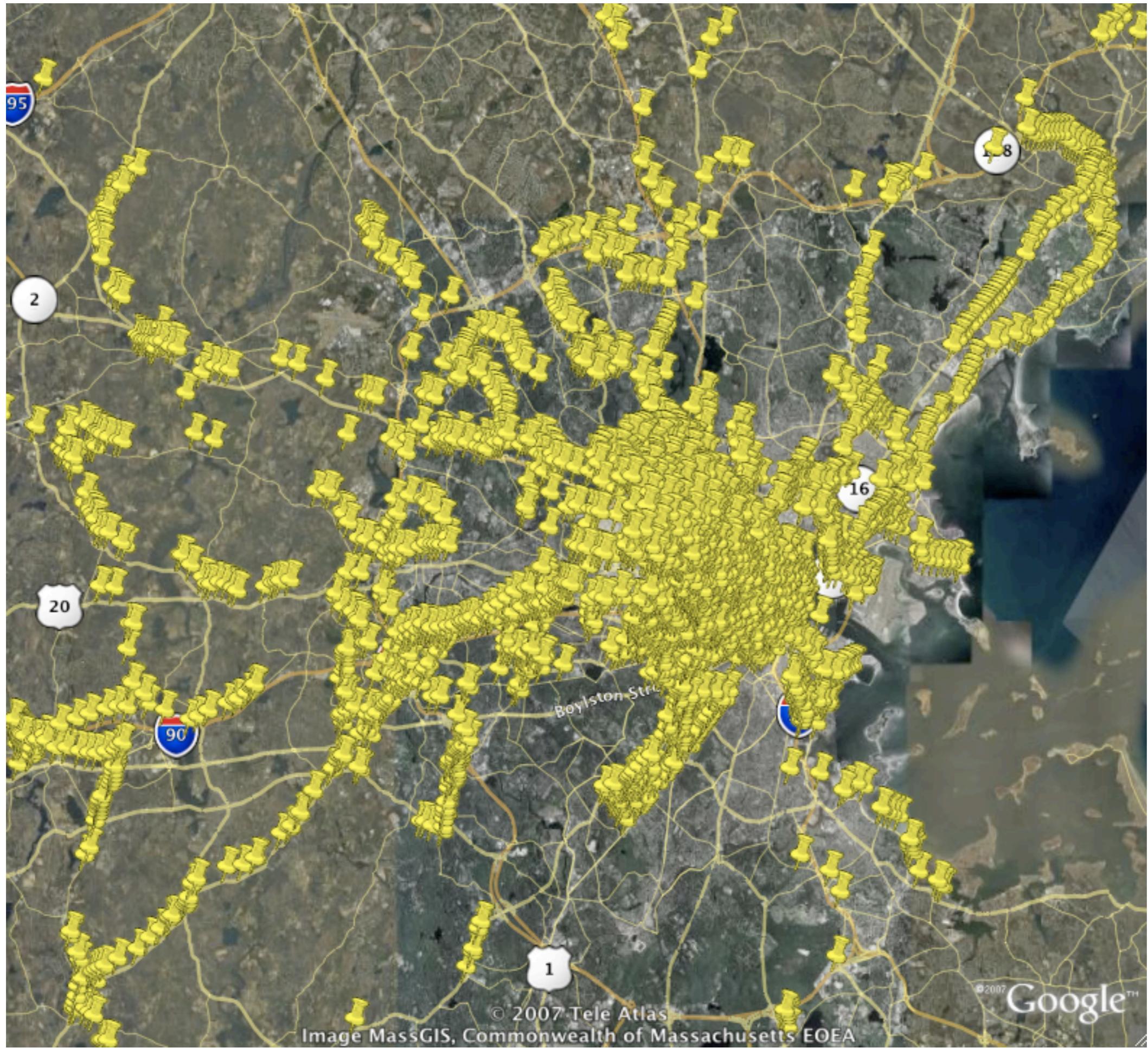






open WiFi connectivity

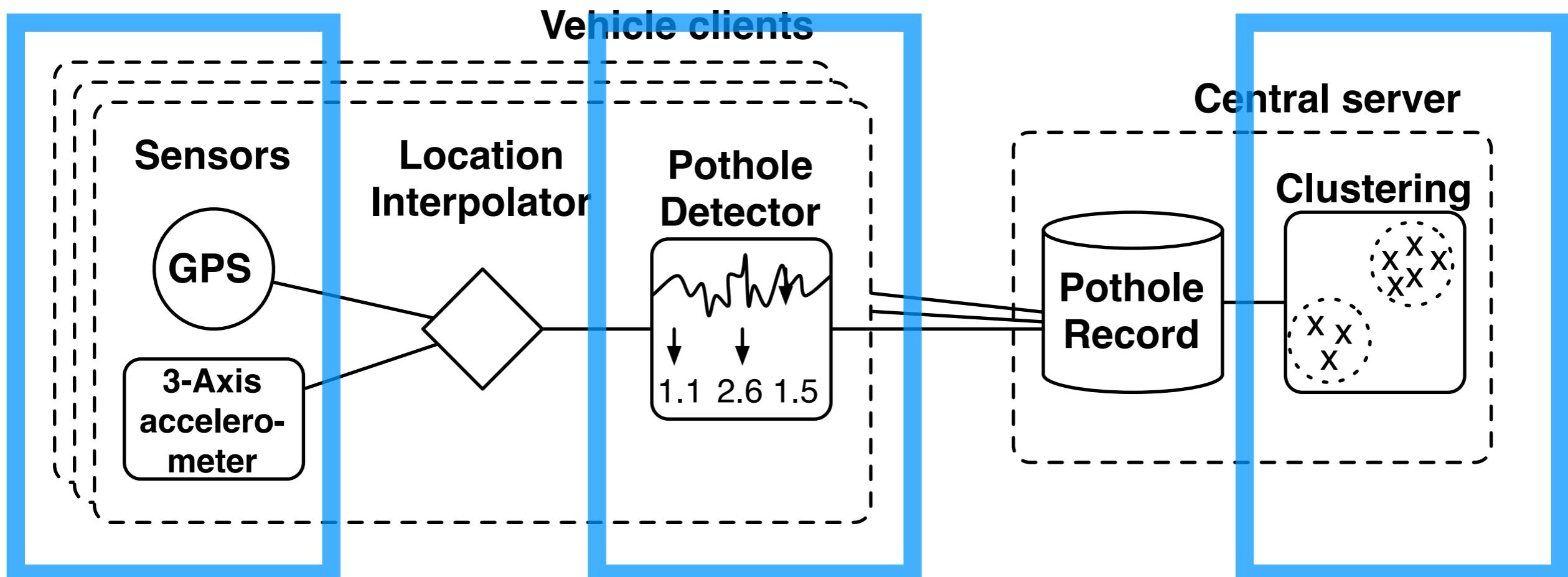




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P2 architecture



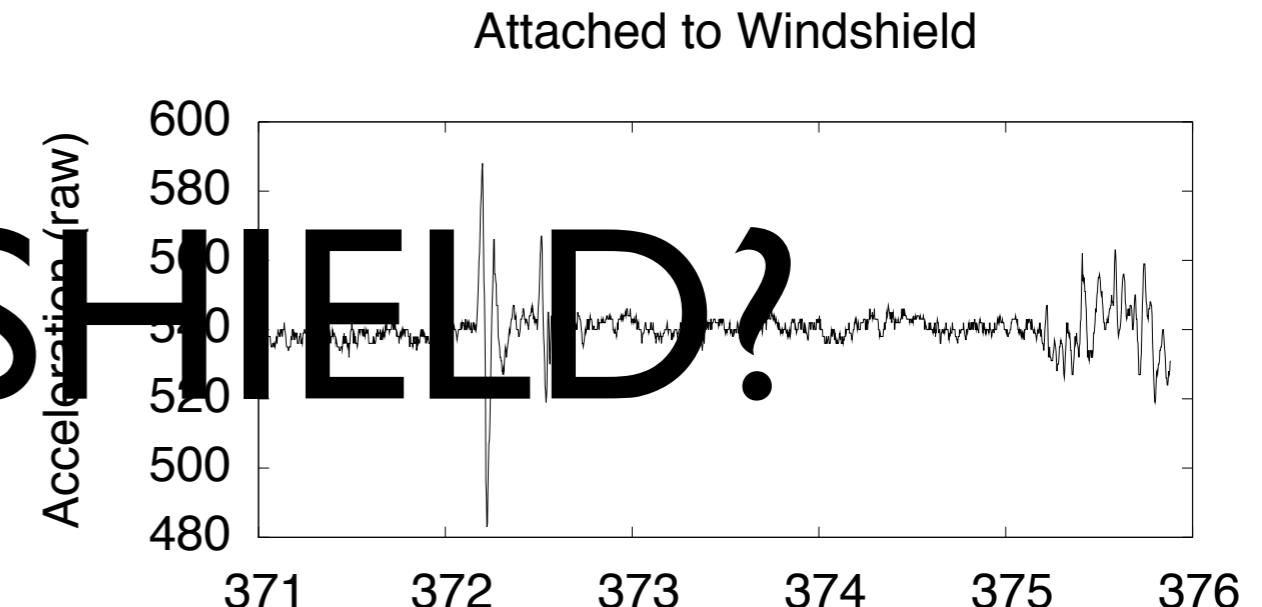
sensor placement



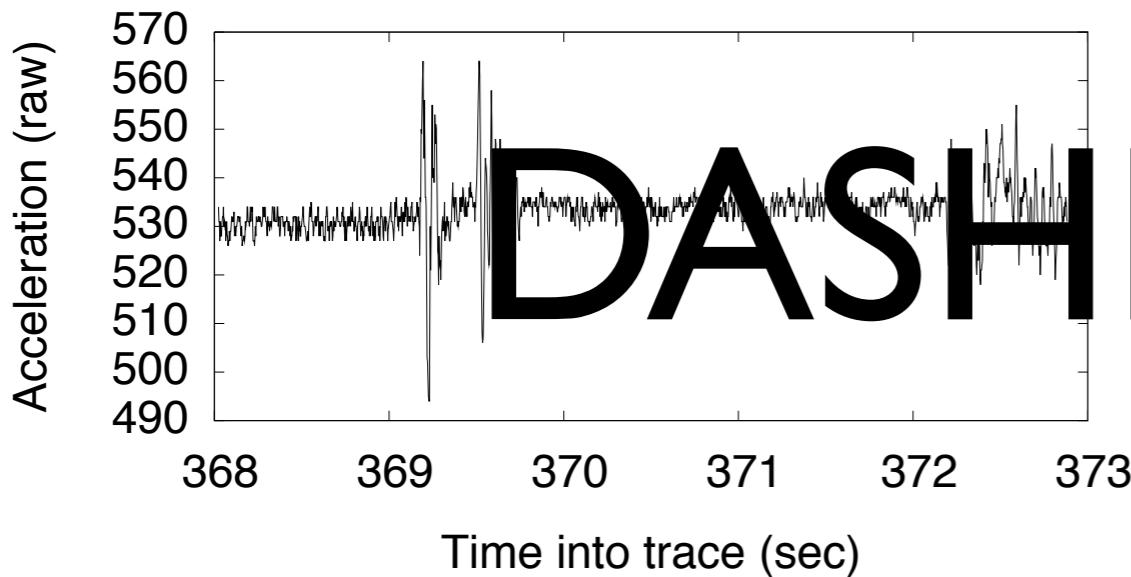
try to stay
inside vehicle

- highly accurate
- difficult mounting
- extreme exposure

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



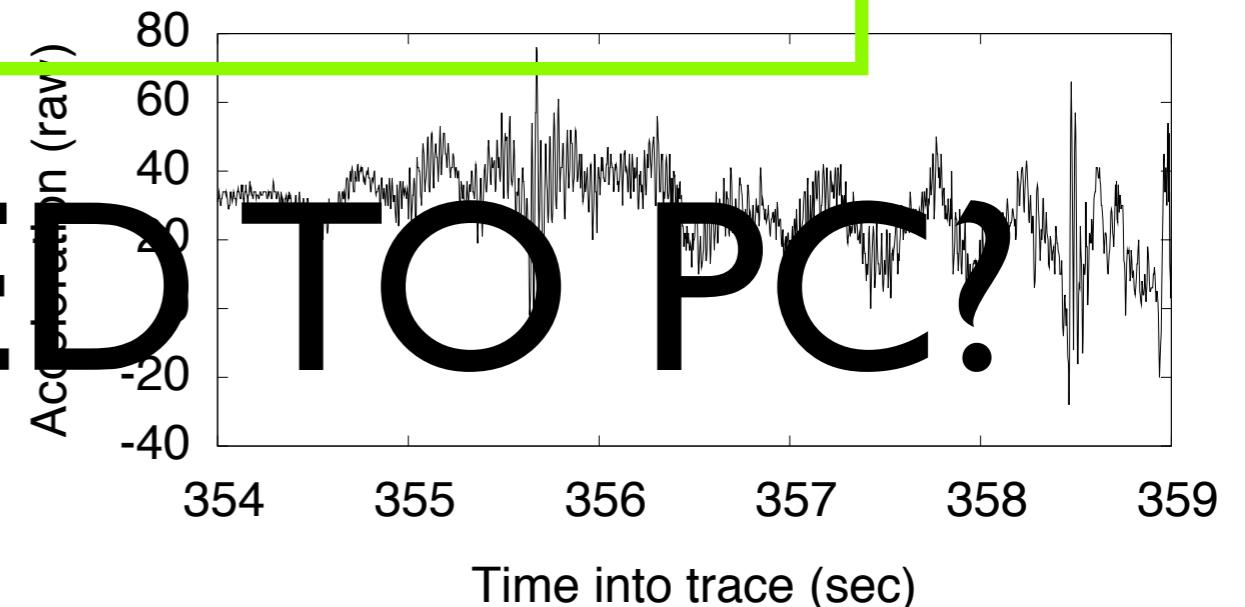
Attached to Dashboard



Time into trace (sec)

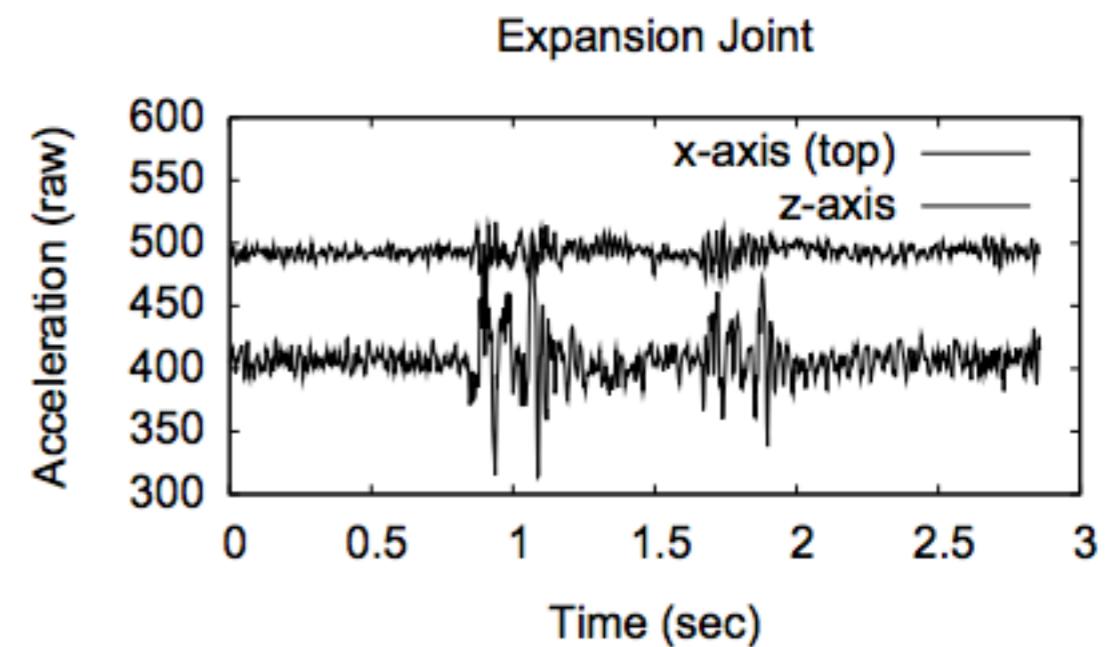
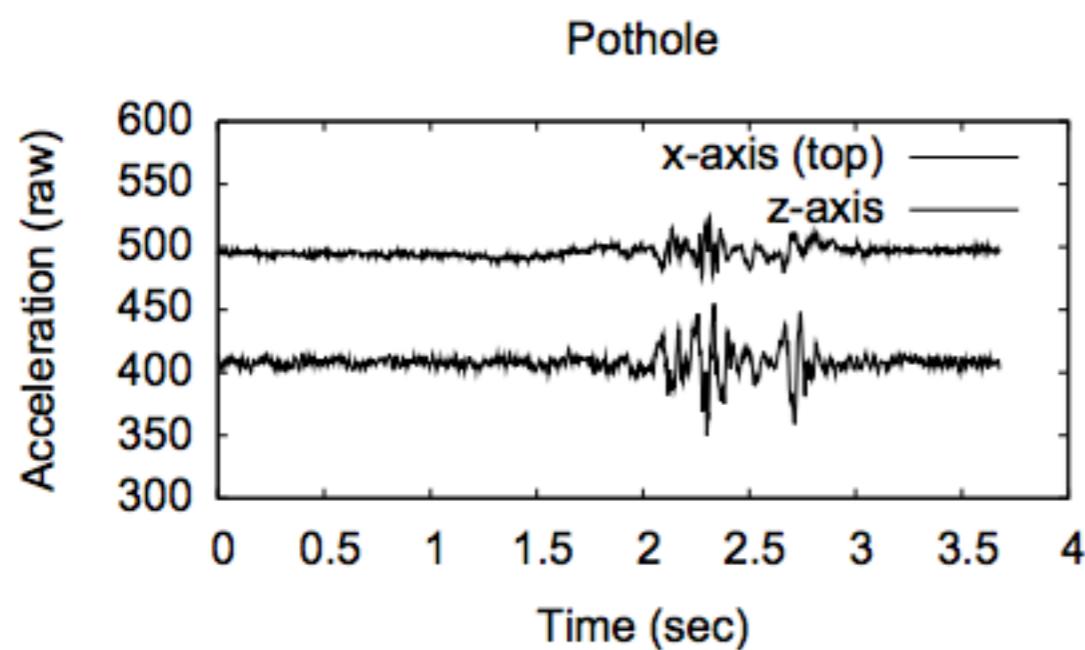
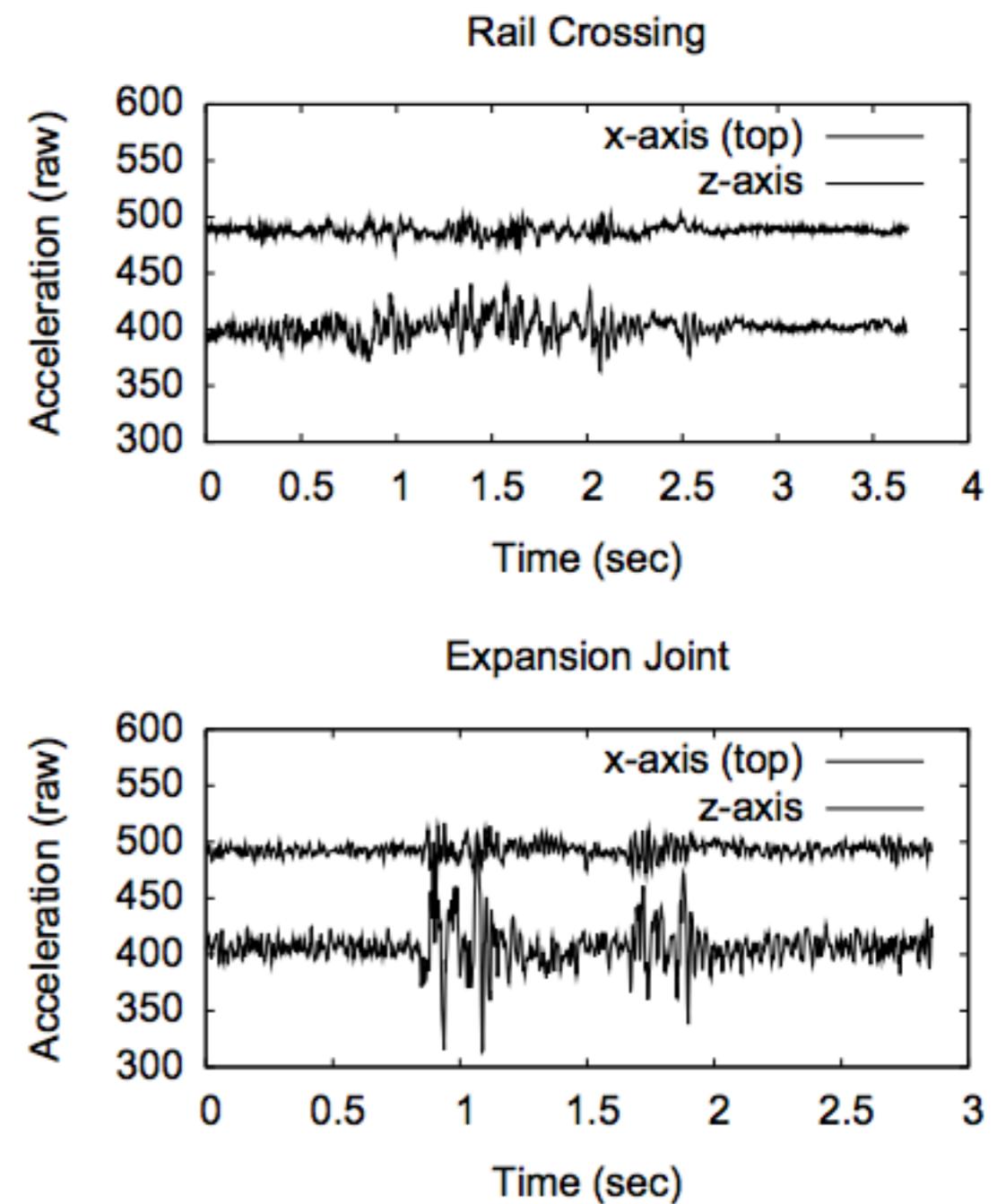
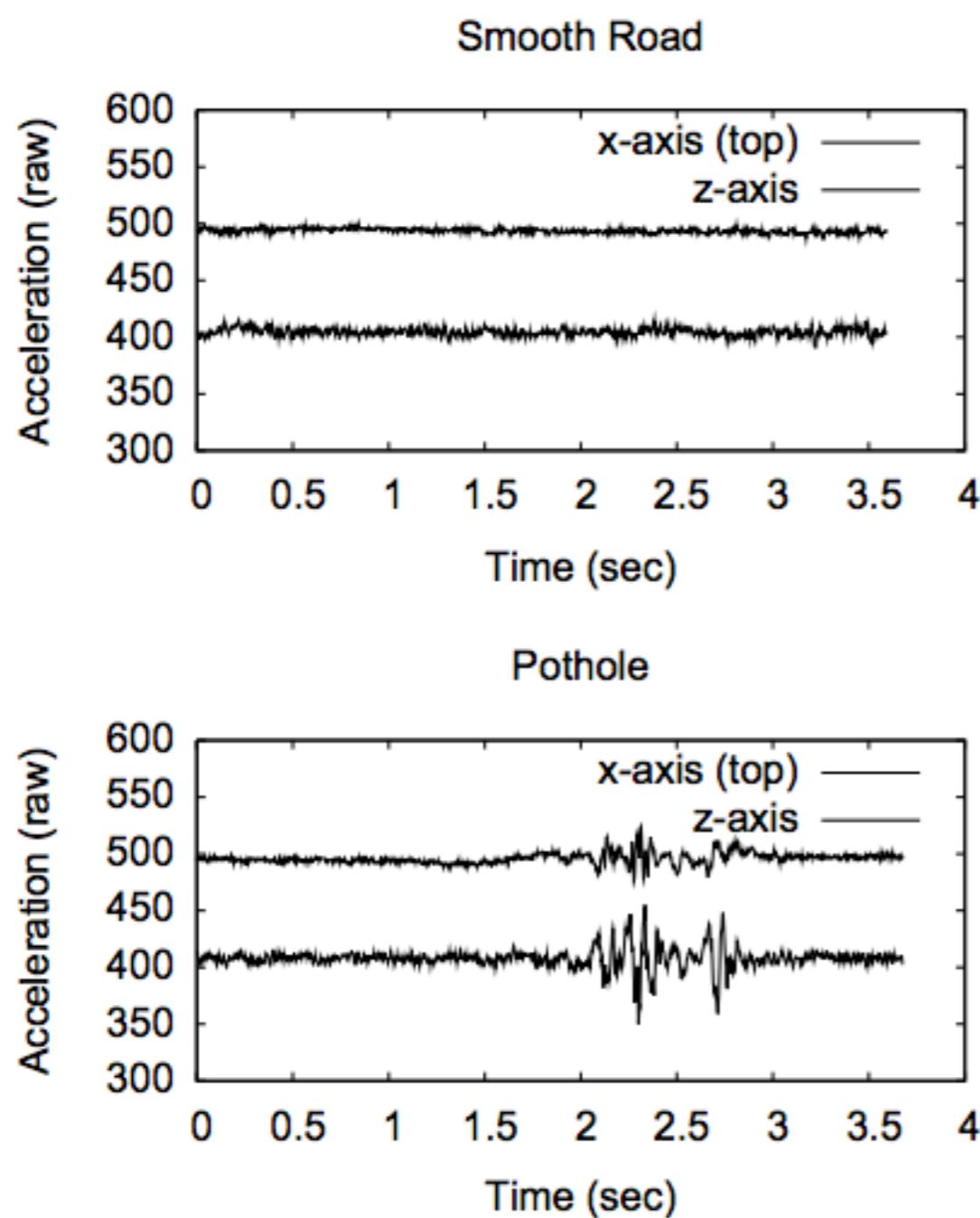
- good signal
- easy to mount
- out of the way

Attached to Embedded PC



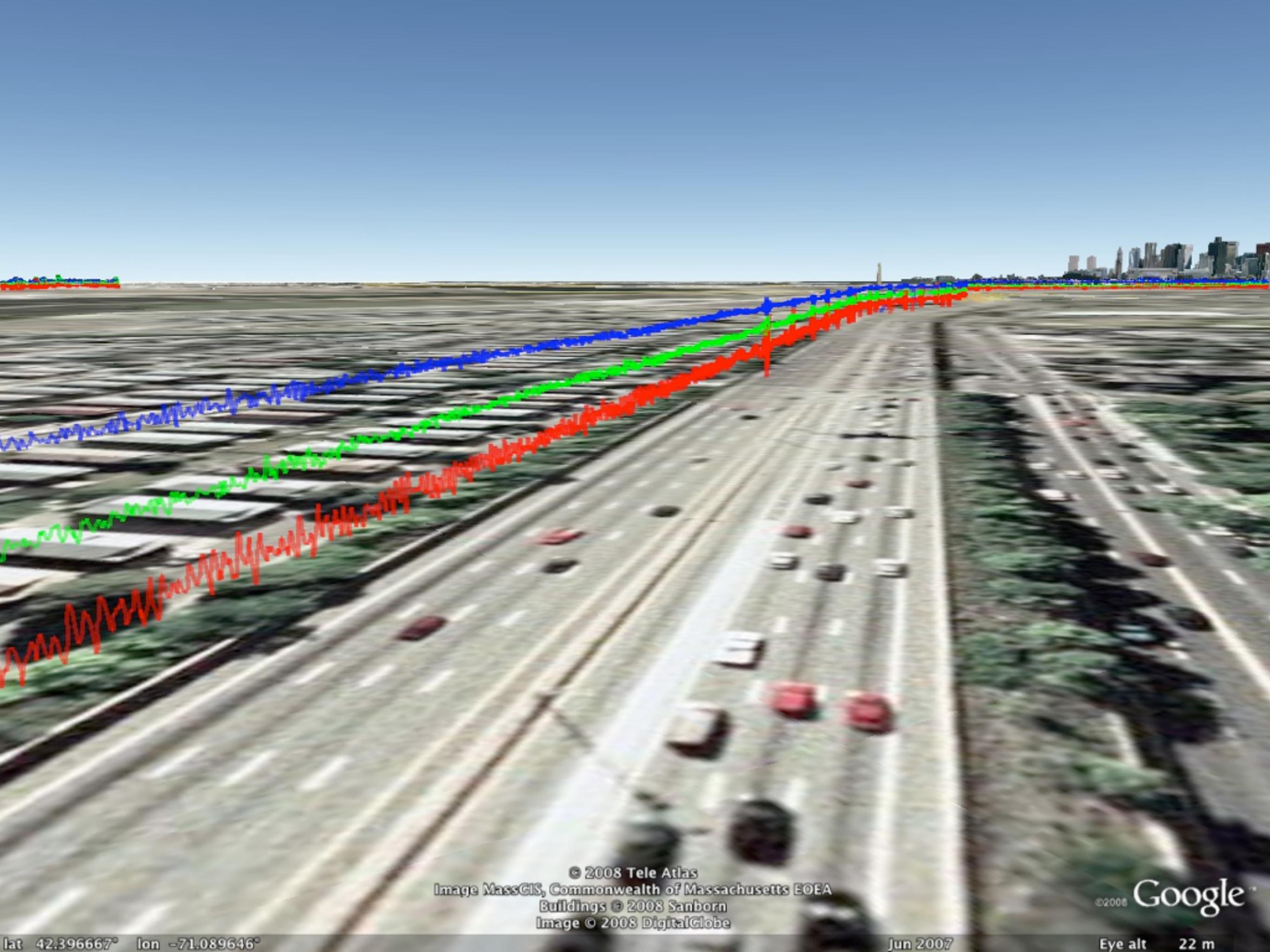
- very poor signal
- no mounting necessary

challenge: “pothole” v. “not pothole”



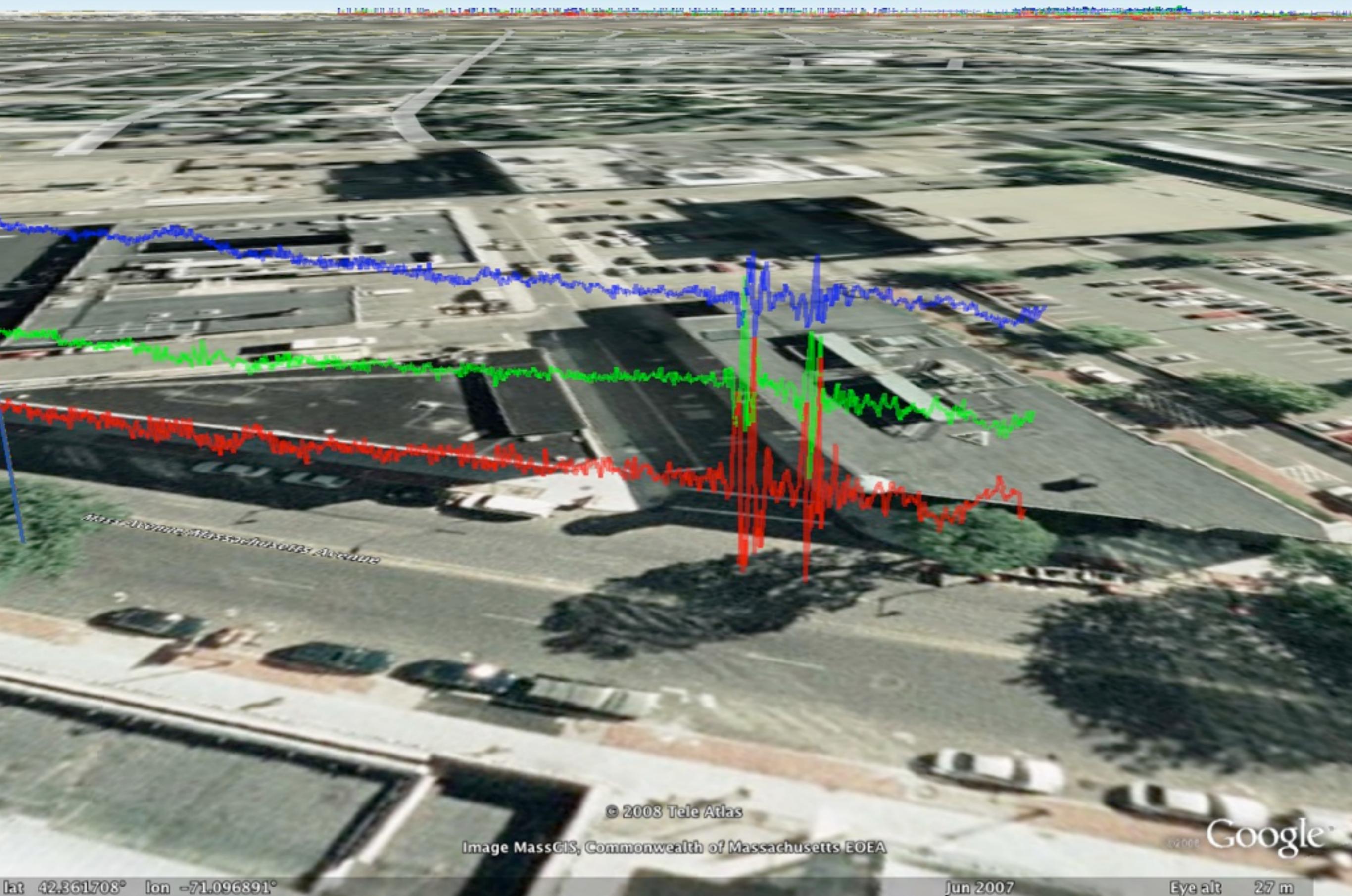
pothole v. not pothole





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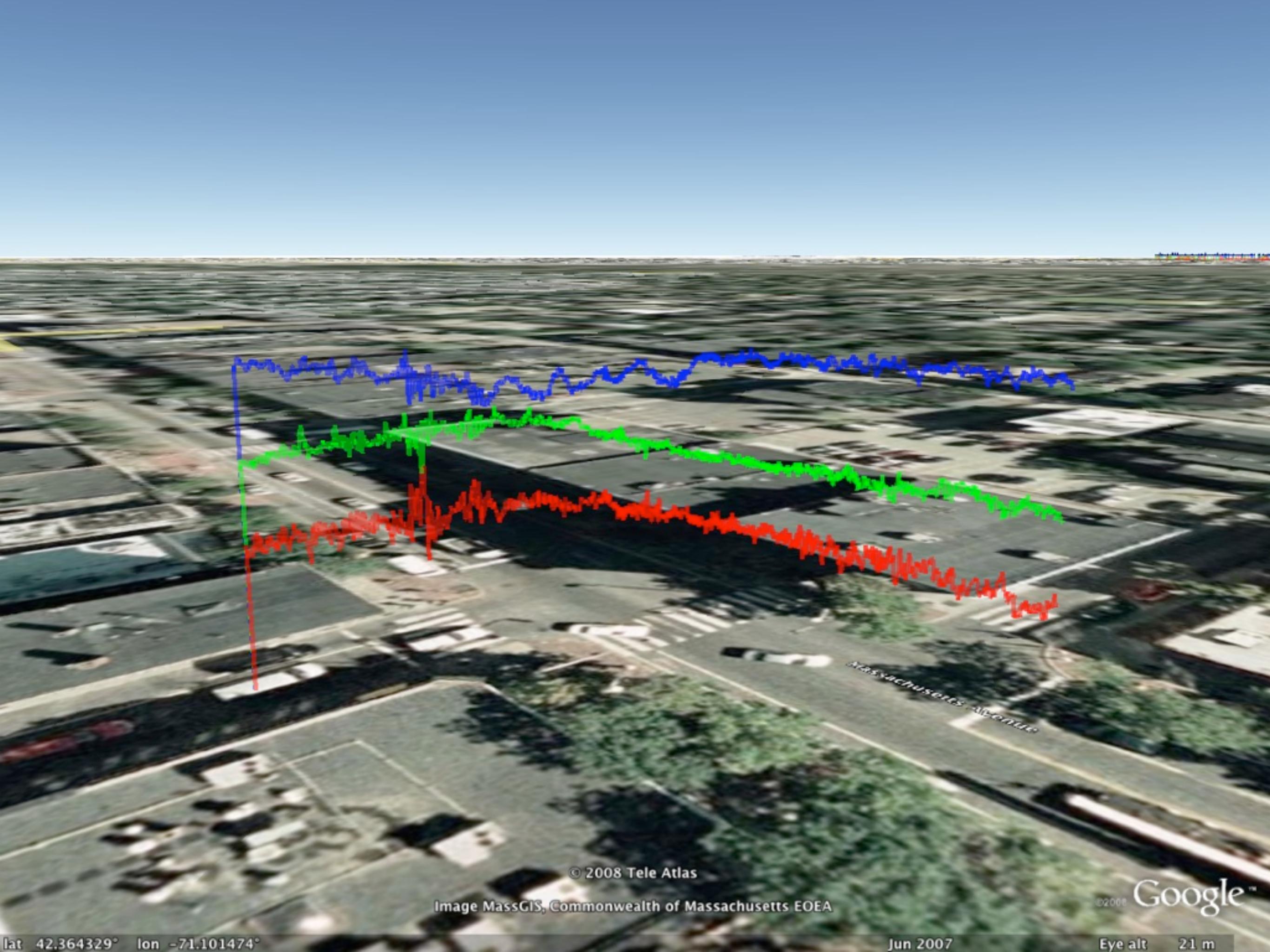
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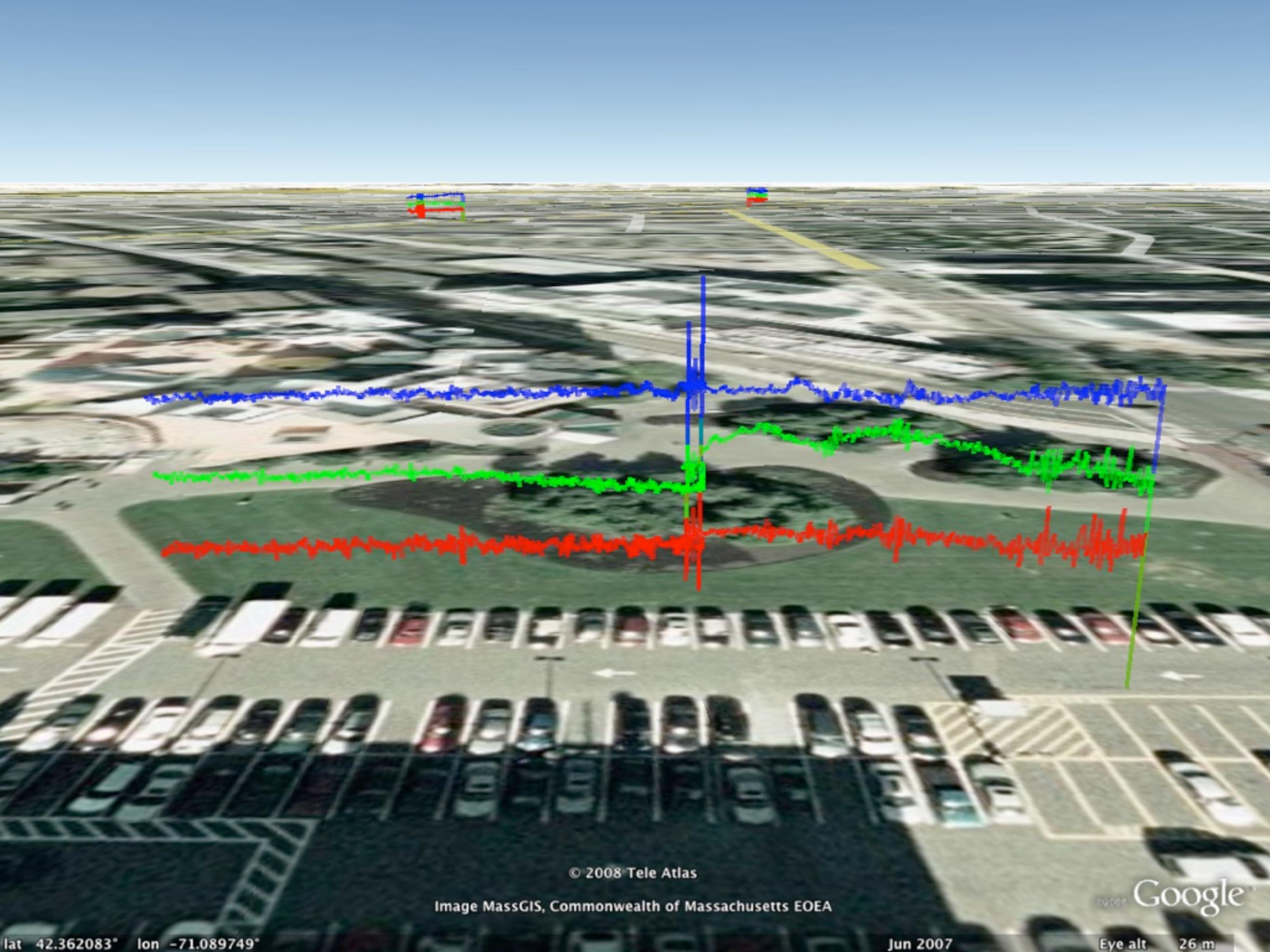
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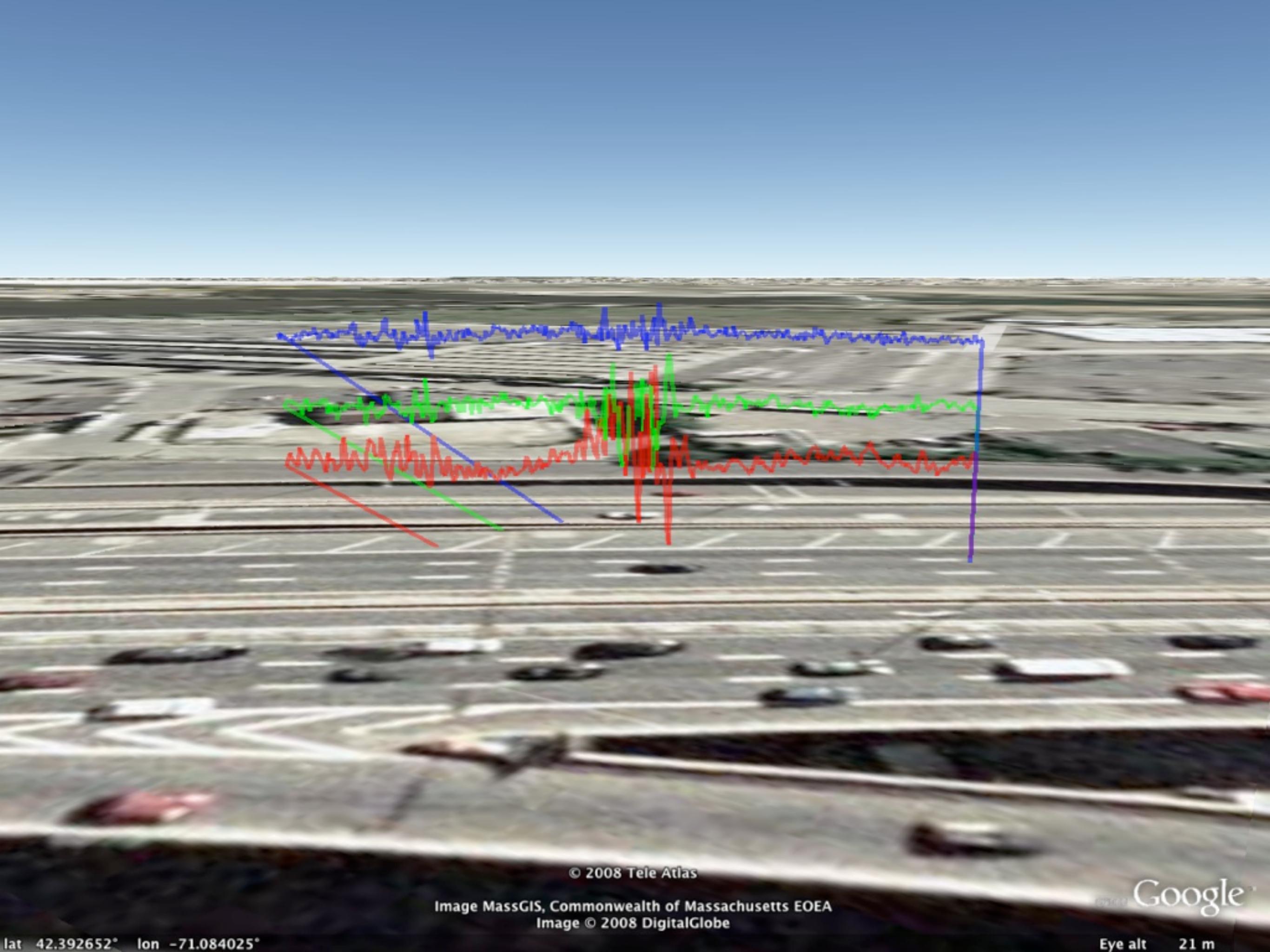
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lat 42.362083° lon -71.089749°

Jun 2007

Eye alt 26 m



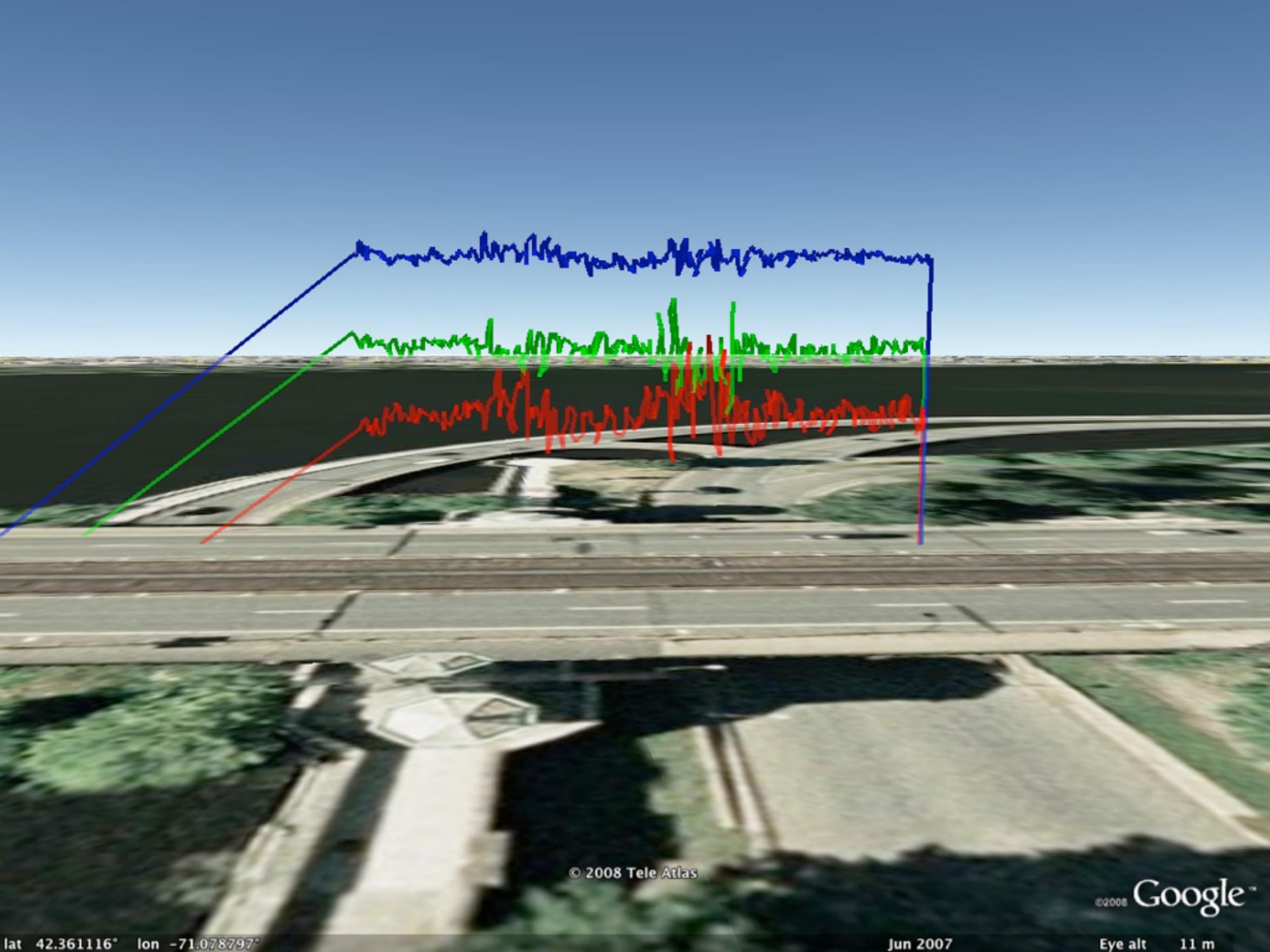
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lat 42.392652° lon -71.084025°

Eye alt 21 m



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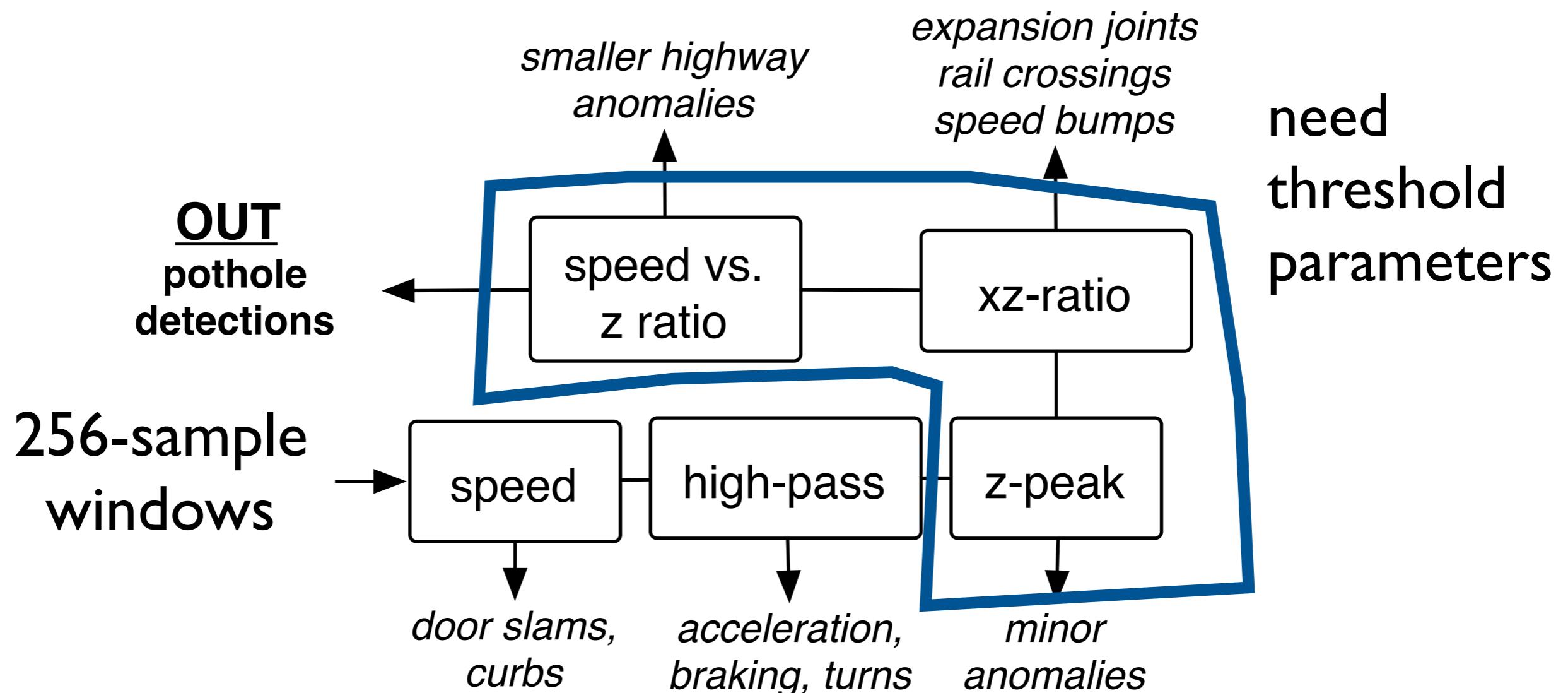
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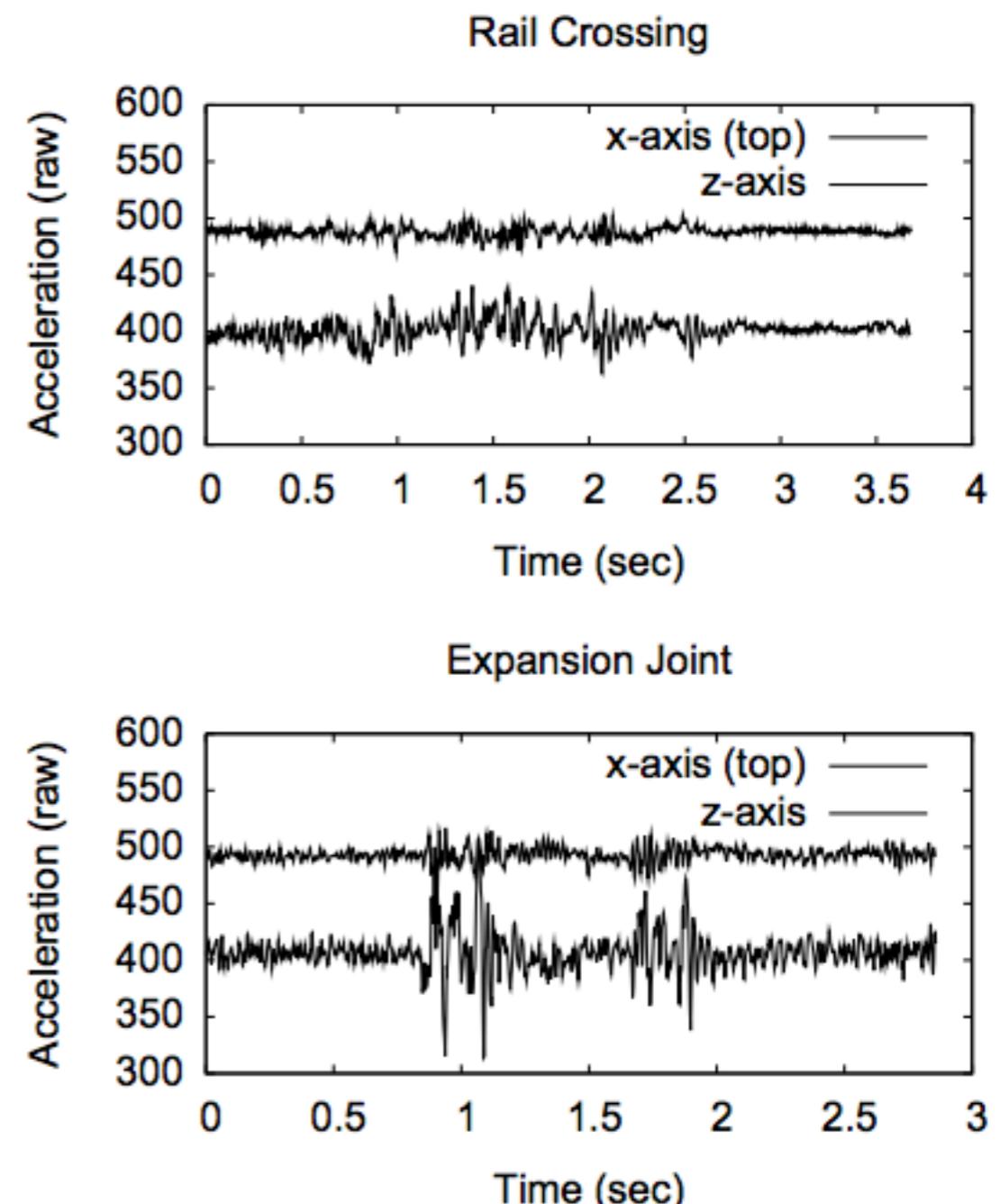
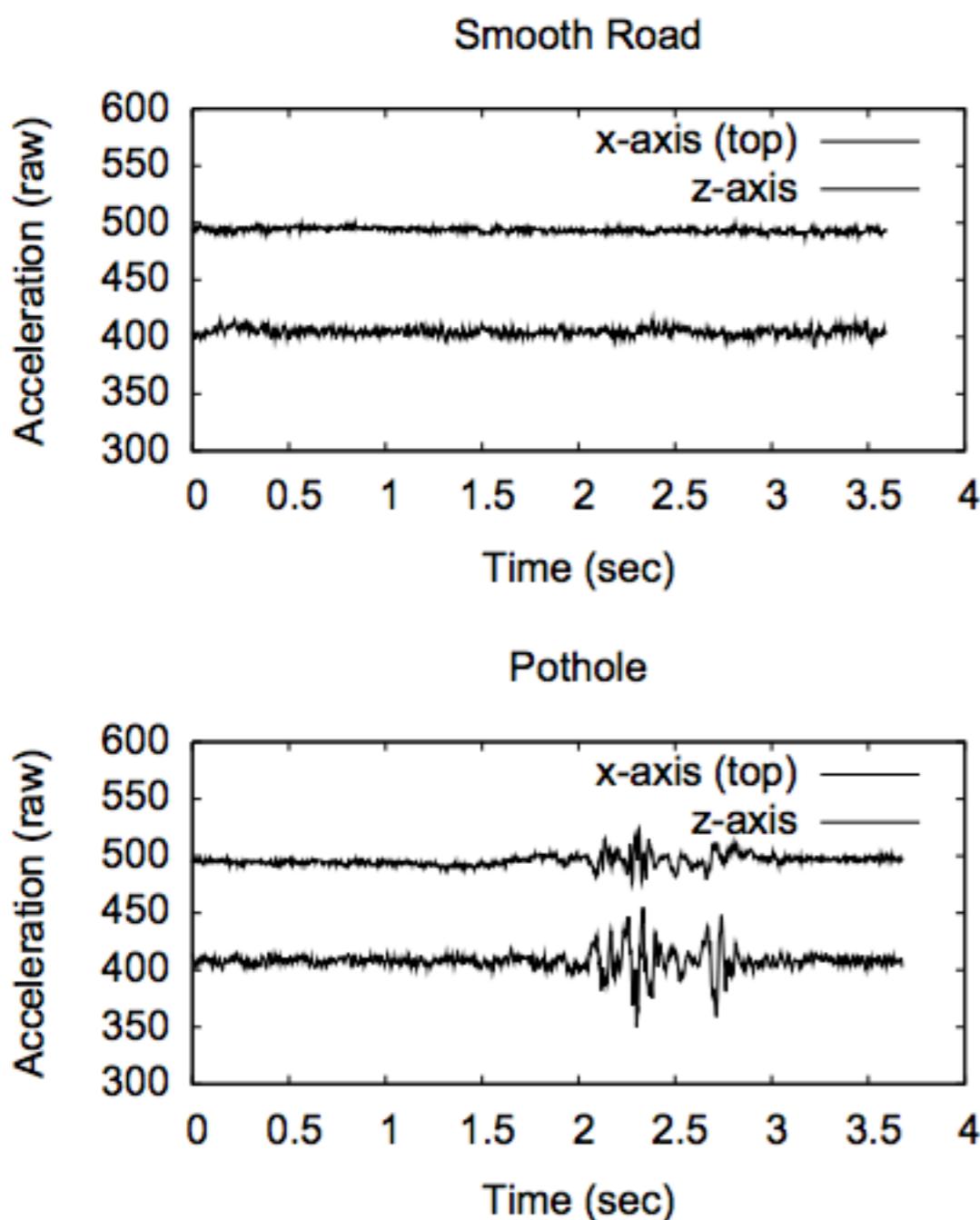
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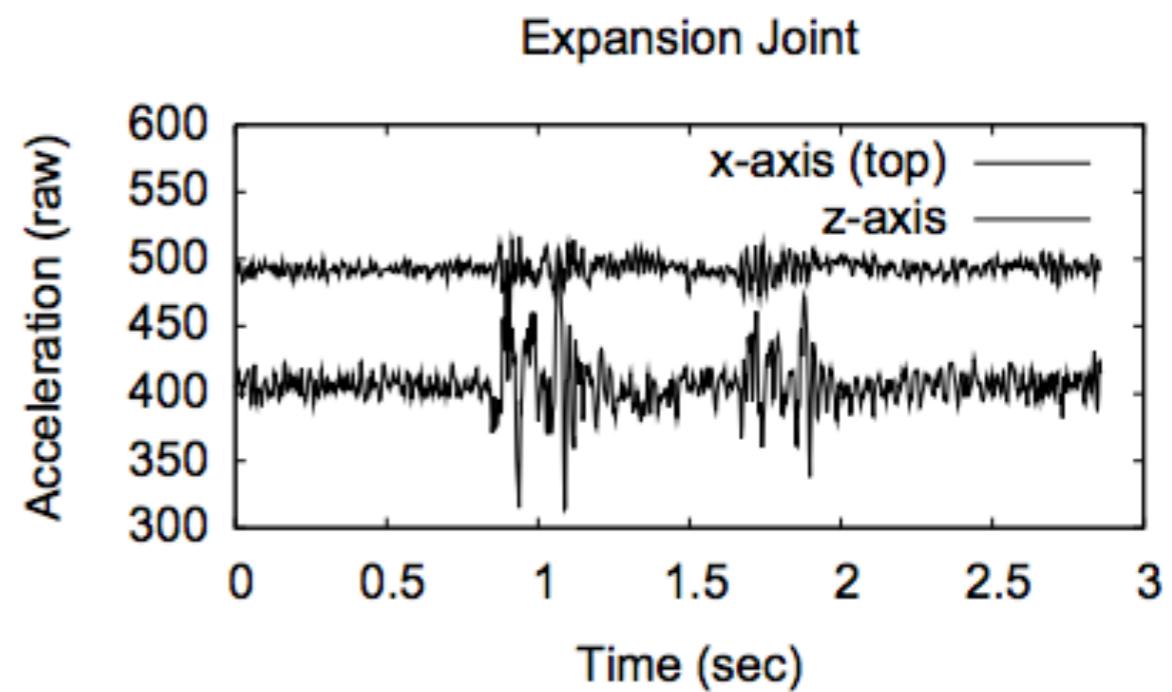
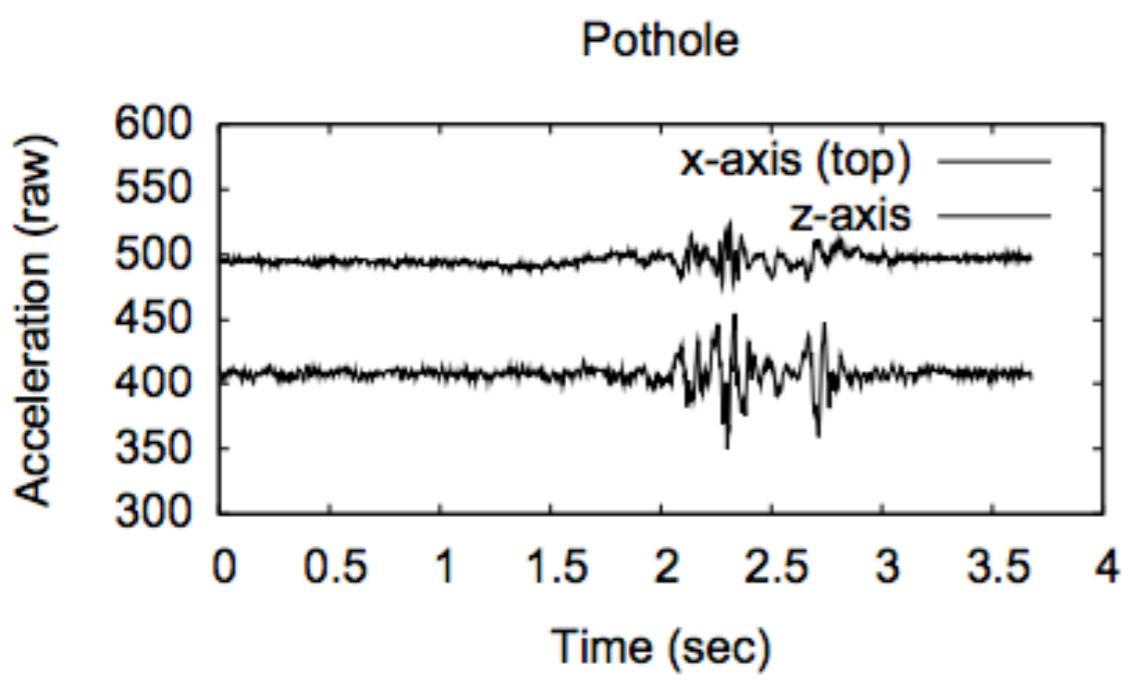
Jun 2007

Eye alt 11 m

P2 detector







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

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

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

detector performance

| Class | before | after | 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



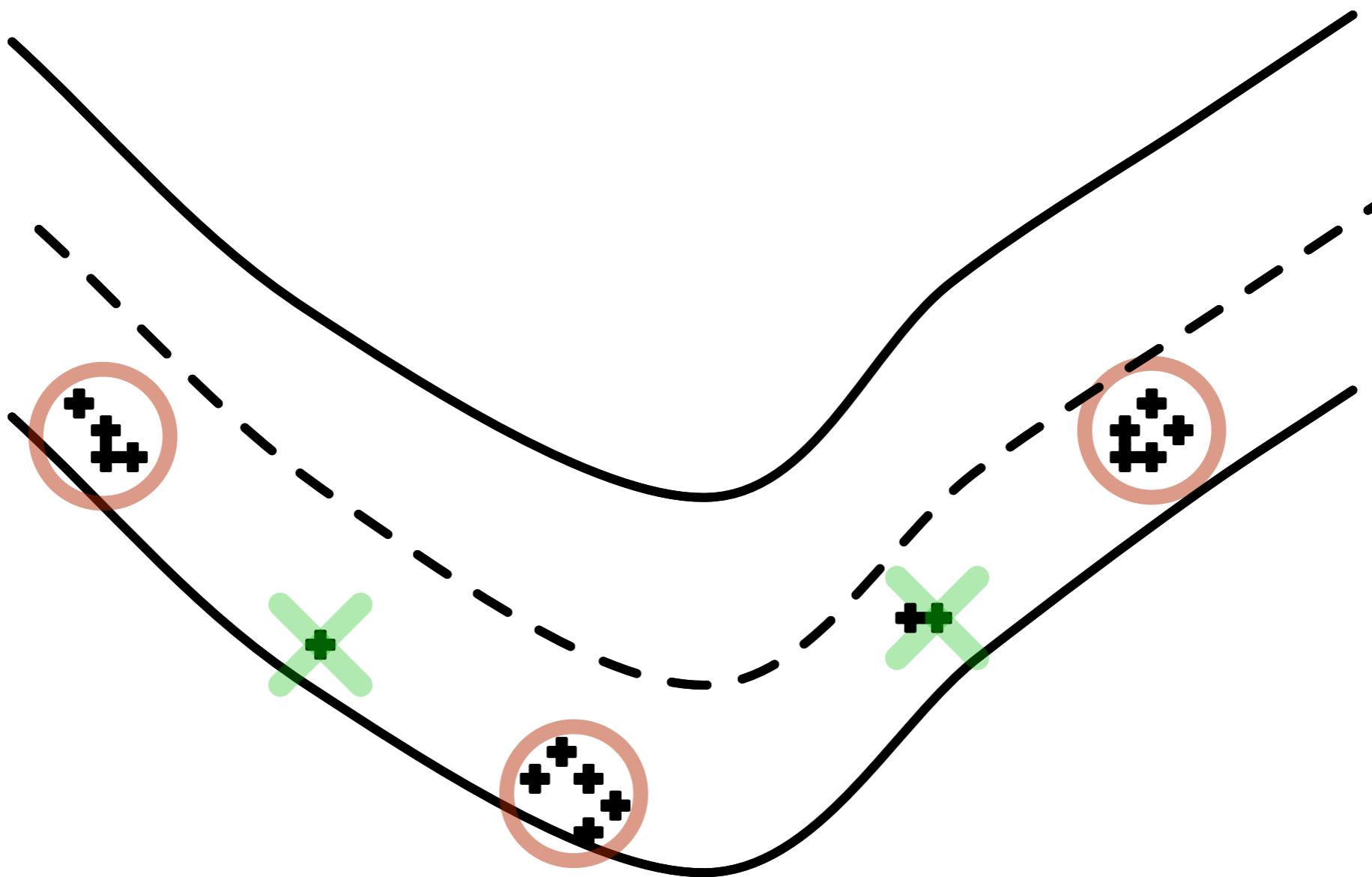
Note: Actual false positive rate is not 7.6%
Why?

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% |



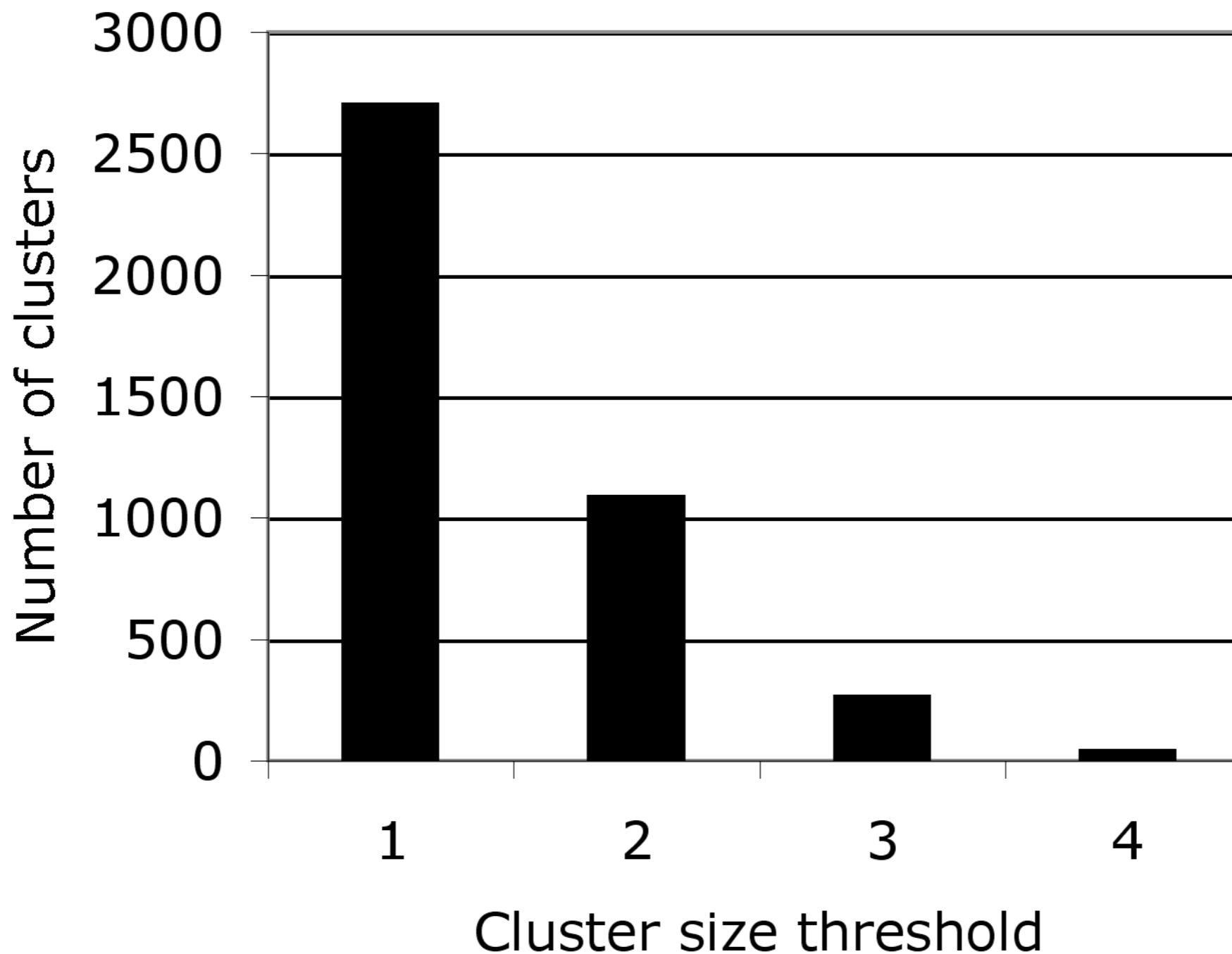
clustering

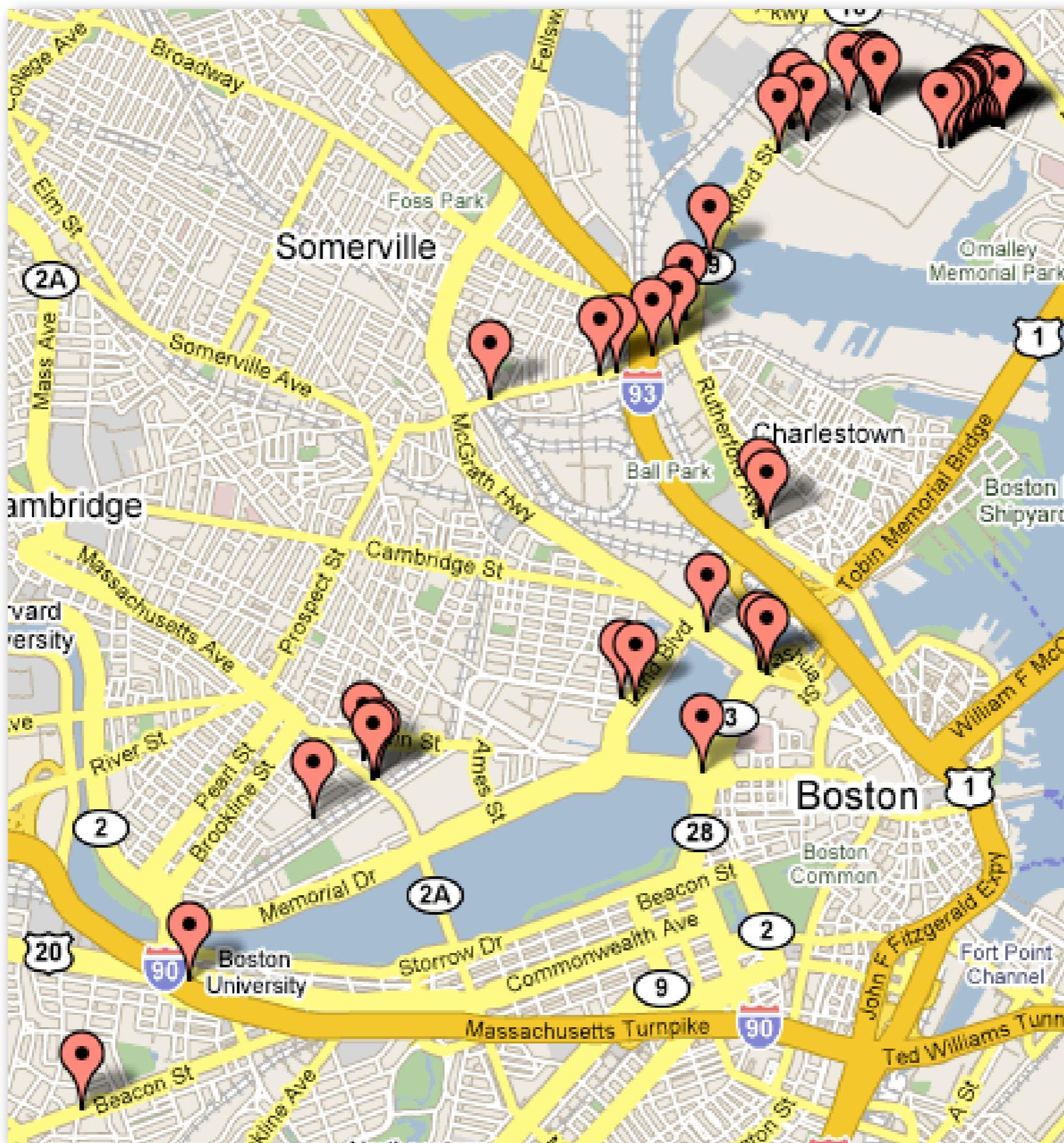


experiments

- 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

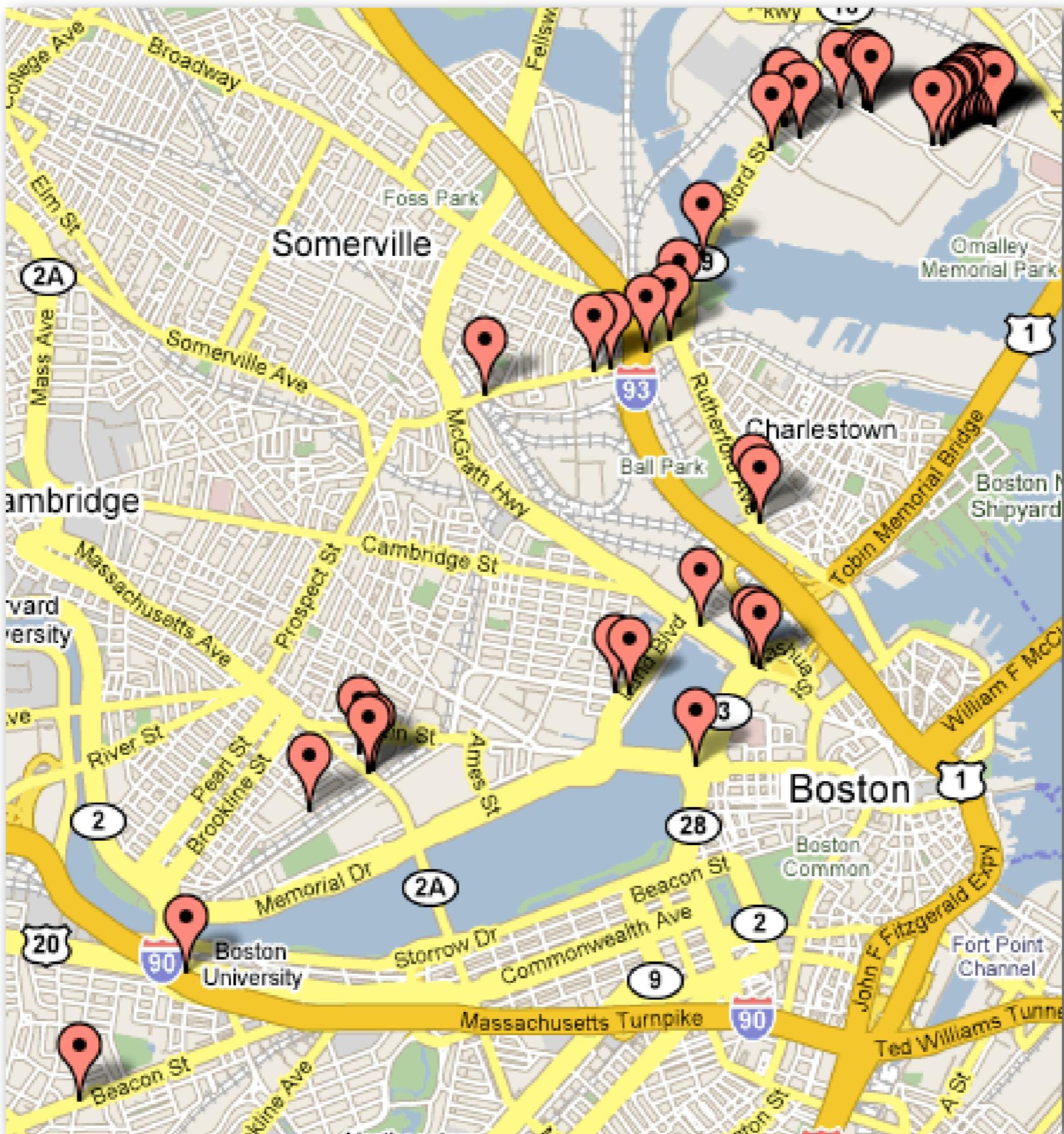


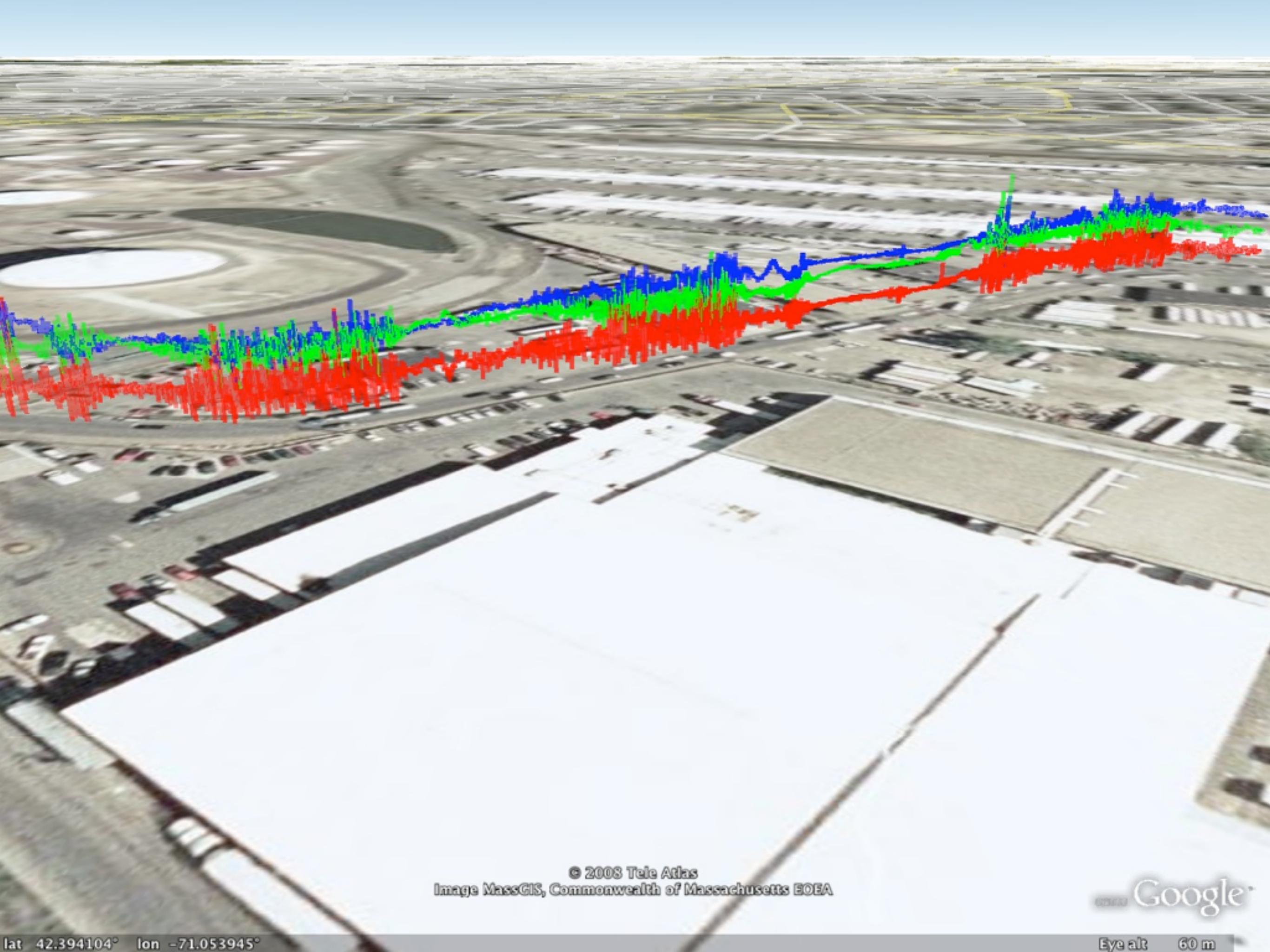


48 spot-checks

| | |
|-----------------------------|----|
| 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