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Transforming Speed Sequences into Road Rays on the Map with Elastic Pathing

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DER SPIEGEL

IEEE SPECTRUM

Elastic Pathing:
Your Speed is Enough to Track you

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Proc. Of UbiComp'14

http://elasticpathing.org/

YAHOO! NEWS

INSIDE SCIENCE TV

From *The Atlantic* CITYLAB

Very Hard Problem (Super-Duper Hard!)

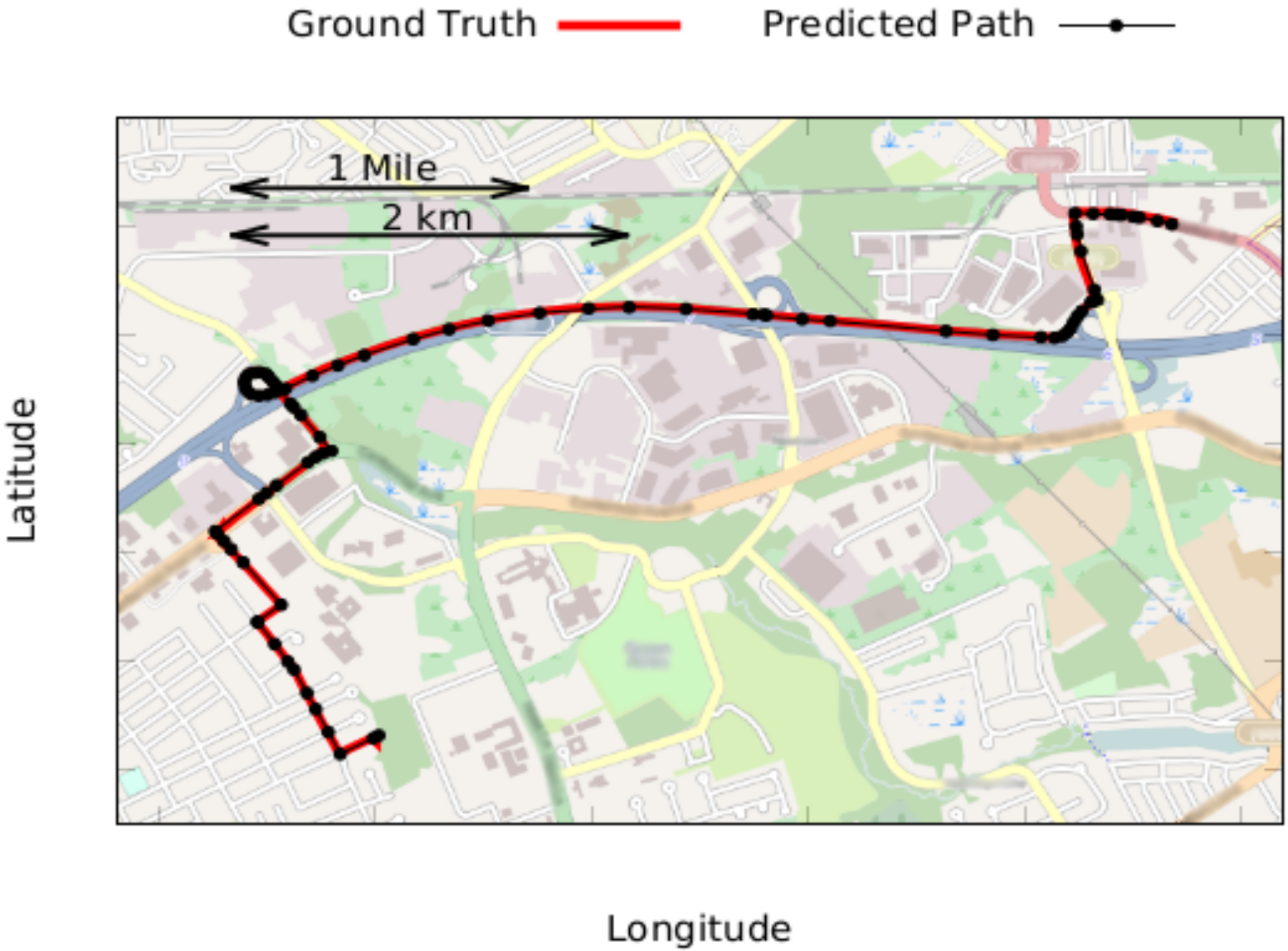
- Is it possible to track you when we just know your:

- Starting location

and

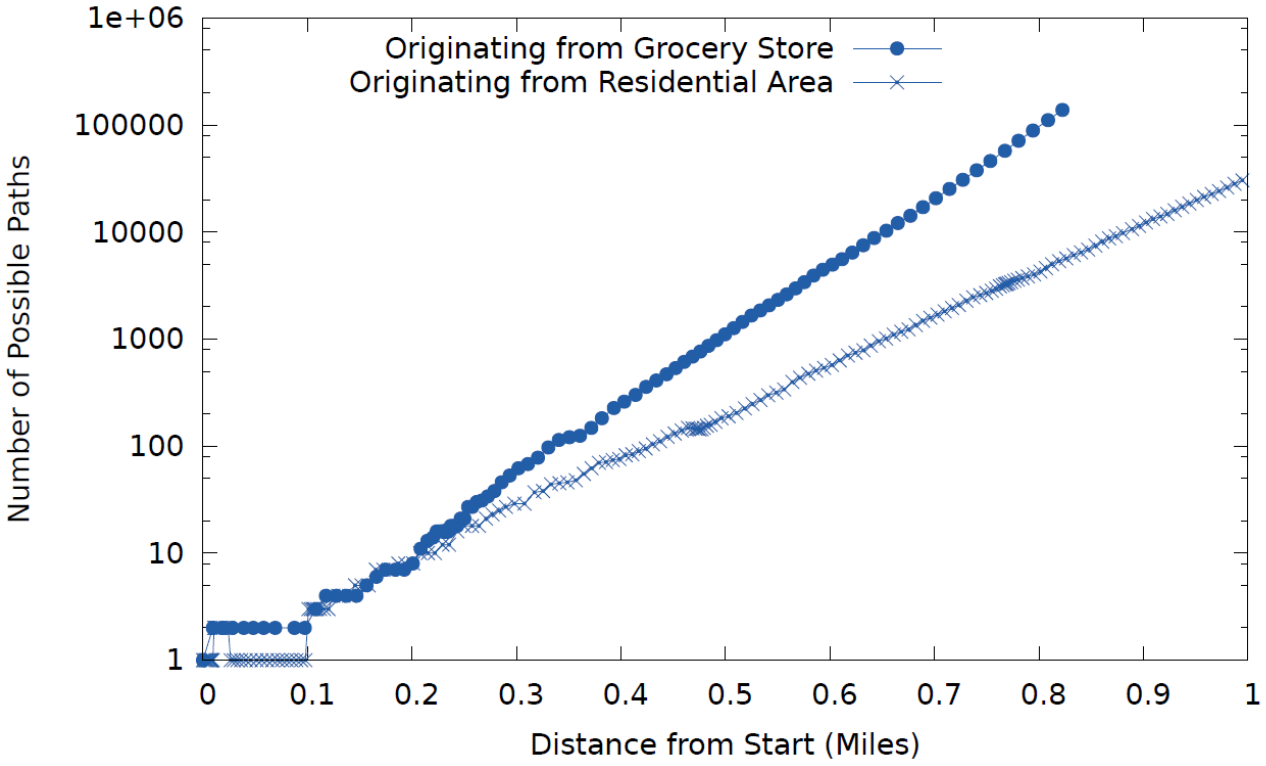
- Your driving speed with timestamps?

Example: Perfect Match



Why Is this Very (Super-Duper) Hard?

1. Large number of possible paths



2. No driving direction

3. Different individual driving habits

4. Various driving environments

5. Hard to determine the turning direction on intersections

Additional Motivation: Usage-Based Automotive Insurance

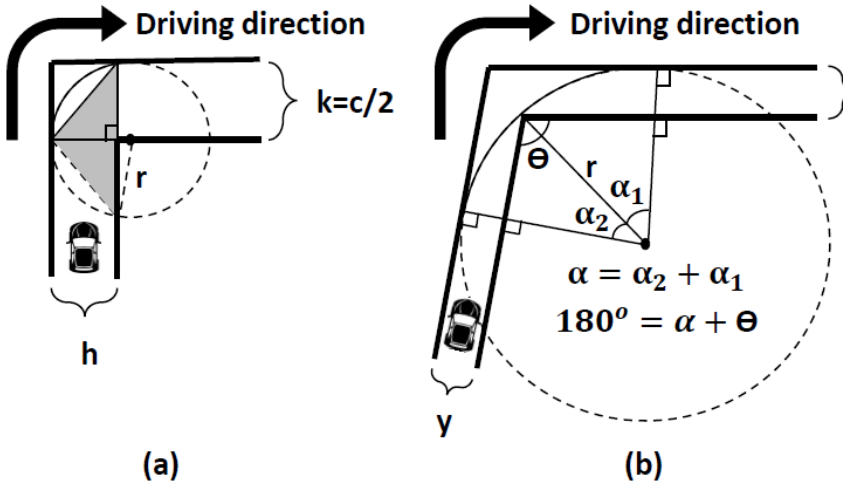
- Install monitoring devices in the car (OBD-II device)
- Collect data (e.g. driving distance, speed, acceleration, etc.) to observe driving behaviors
- Identify safe drivers, encourage safe driving
- Reduced premiums for joining this new policy

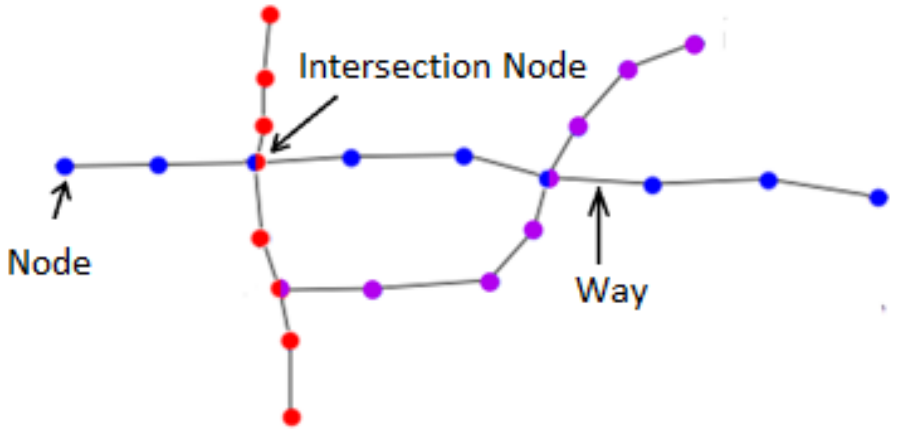
Additional Motivation: Usage-Based Automotive Insurance

- Some companies claim to only collect speed data to preserve privacy
- Examples
  - PROGRESSIVE: Snapshot device
  - Allstate: DriveWise device
- **Starting location: home address known by insurance companies**

Some assumptions

- Possible causes for a stop
  - Encounter an intersection
  - Reach final destination
  - At the starting location
  - Other cases (exclusive in the algorithm):
    - people crossing streets, bumps in the road, traffic, accidents, etc.
- Speed restriction for different turning angles
- Use of OpenStreetMap (OSM)





Key Idea: Elastic Pathing Algorithm (simplified)

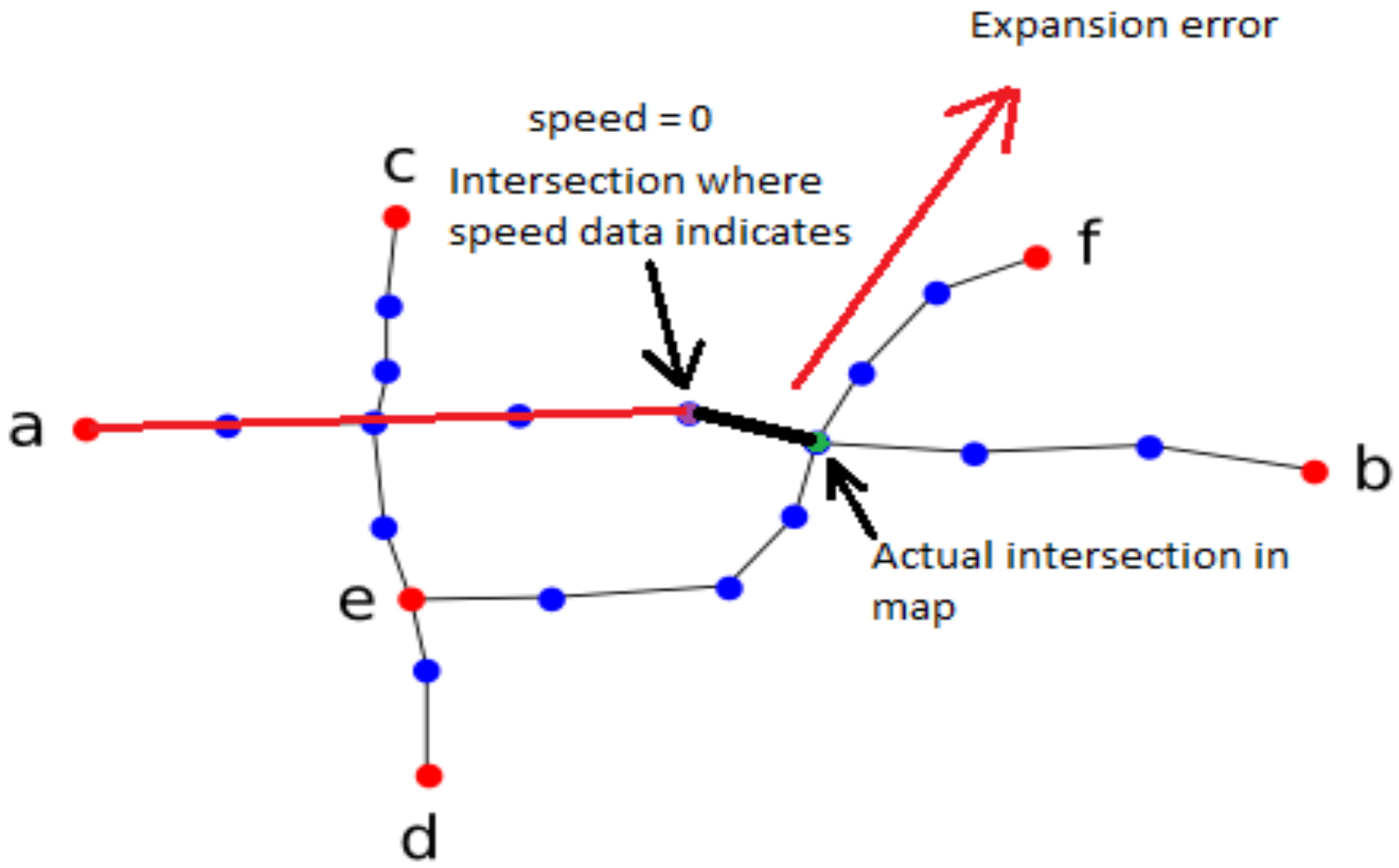
- Accumulate distance from speed
- Select the path with smallest error
- Check for speed limitation
- Advance the path and accumulate the error
- Add in new possible paths
- Sort possible paths according to the overall error
- Repeat until complete

Path Error Detection

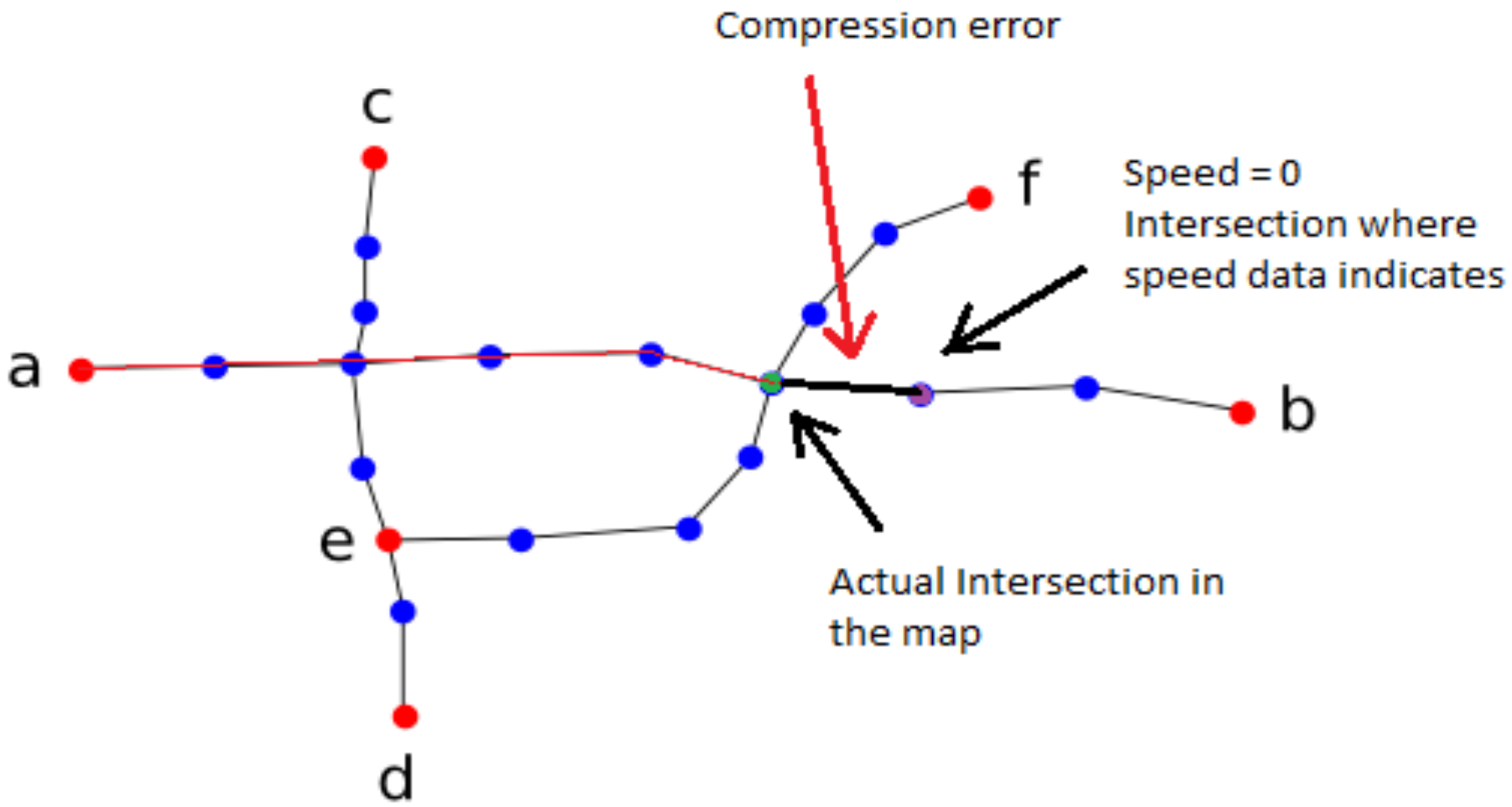
- Match speed data with actual paths in the map

- Path error occurs when following situations happen
  - Stopping in the mid-way
    Find an nearest intersection in the map
    (Path expansion and path compression)
  - The speed is too fast to make the turn
    Find the slow speed sample nearby
    (Advance speed samples and rewind speed samples)

Path Expansion



Path Compression



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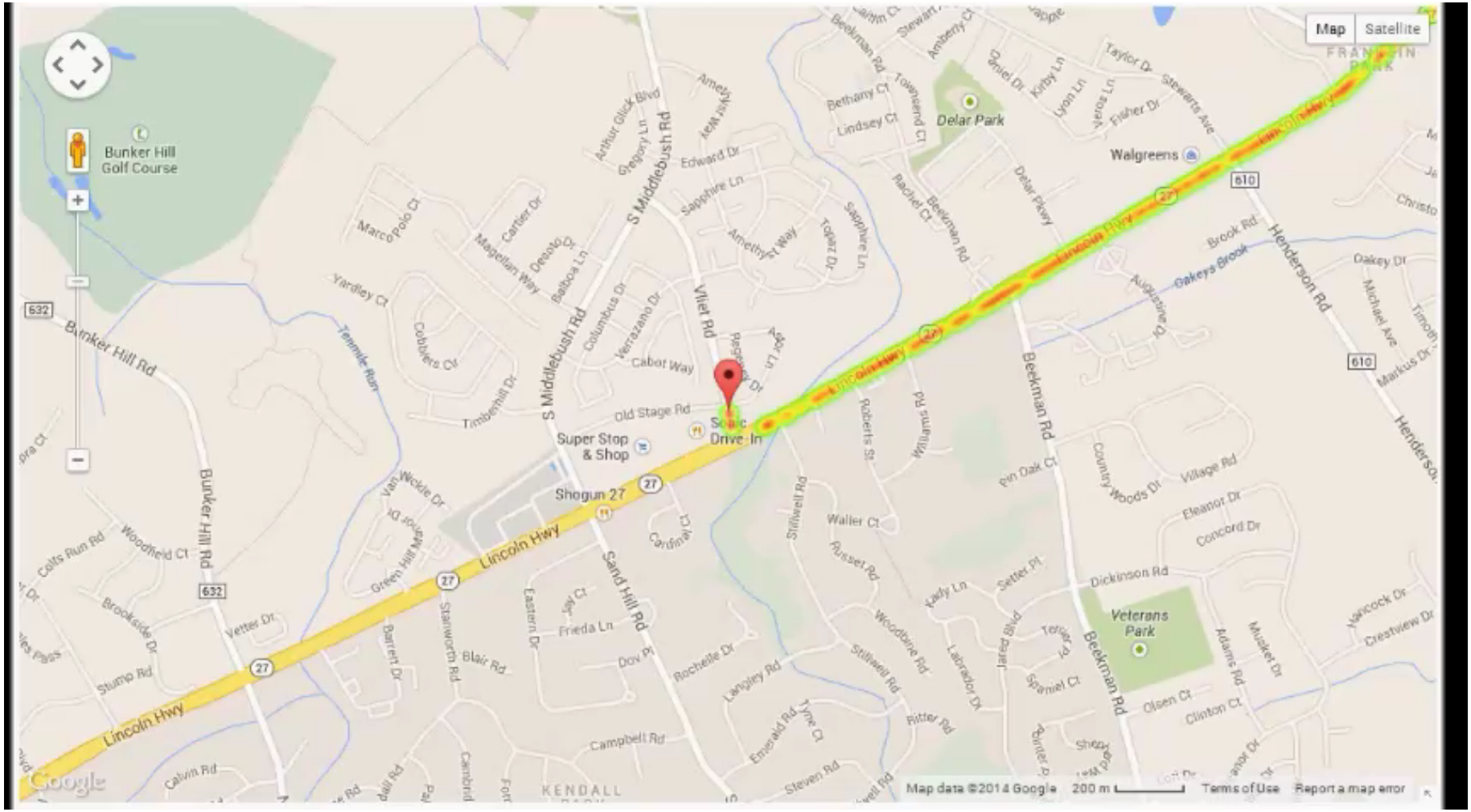
Demo, not available in PDF, please see http://elasticpathing.org for demo videos



Two Real-World Datasets

- Central New Jersey dataset (sub-urban area)
  - 6 volunteers with 254 traces
  - Average trip length 4.65 miles (min 0.38 miles, max 9.96 miles)
- Seattle dataset - Microsoft Research Group (urban area)
  - 21 volunteers with 691 traces
  - Average trip length 2.6 miles (min 0.59 miles, max 19.9 miles)

Finding: Accuracy Differs with Drivers

Traces with Low Estimation Accuracy: Major Factors of Cause

- **Homogeneity of roads**: similar roads (e.g. same speeds, similar intersection intervals, areas built in a grid)
- **Unpredictable stops**: stops not near any intersection caused by traffic, constructions, etc.
- **Very few number of stops**: no or very few stops does not provide much information about intersections.
- **Mostly slow speeds**: high speeds help rule out turns and constrain paths to a few major roads
- **Limitations of OSM**: Nodes connected by the OSM are sometimes impossible to reach in real driving: connecting a road to a bridge over it, entering non-driving paths, etc.
- **Unpredictable direction turnarounds**: dead-end turnaround, illegal u-turn, etc.

Summary

- New Jersey dataset
  - 17% traces: error less than 250 meters (0.16 miles)
  - 24% traces: error less than 500 meters (0.31 miles)
- Seattle dataset
  - 16% traces: error less than 250 meters
  - 28% traces: error less than 500 meters

- More information and full demo video at:
- http://elasticpathing.org/

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Thank you!

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