Civil, Architectural and Environmental Engineering

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The University of Texas at Austin

Inertial measurement unit-based traffic flow monitoring

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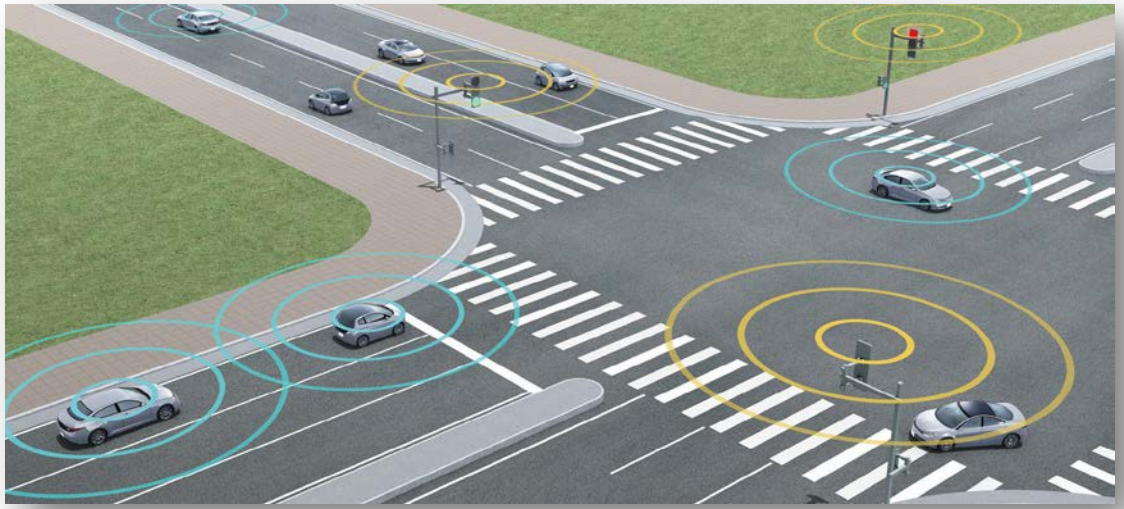
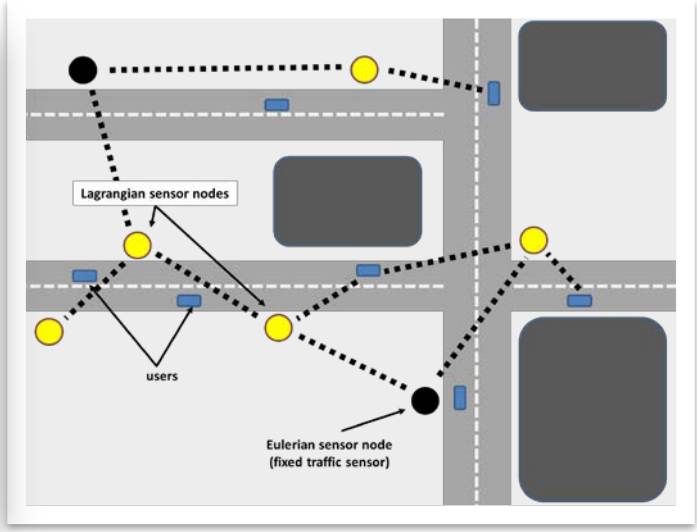
Background

- Overall societal cost of traffic congestion is very high: $818/person/year (USA, 2011), 2.9 billion gallons of fuel wasted/year
- Traffic control could dramatically reduce the societal cost and delays associated with congestion
- Traffic control requires high resolution traffic maps and forecasts, which we do not have yet

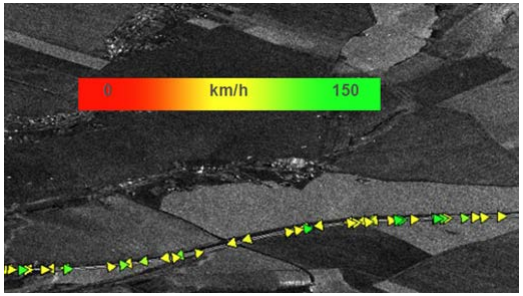
Mobile traffic sensing

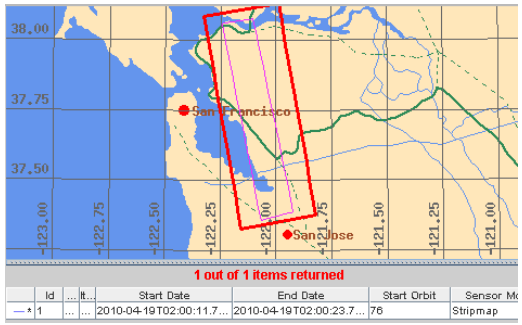
- Within a few years, all new vehicles will have short-range communications, either between vehicles (V2V) or with infrastructure (V2I)
- All new vehicles will become probe vehicles, capable of sensing traffic conditions



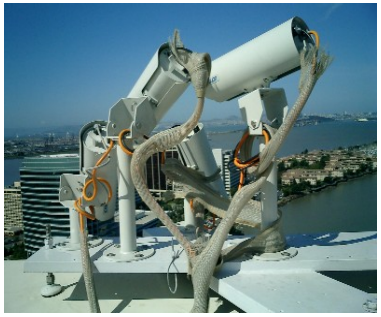


Traffic data sources





From the sky or space

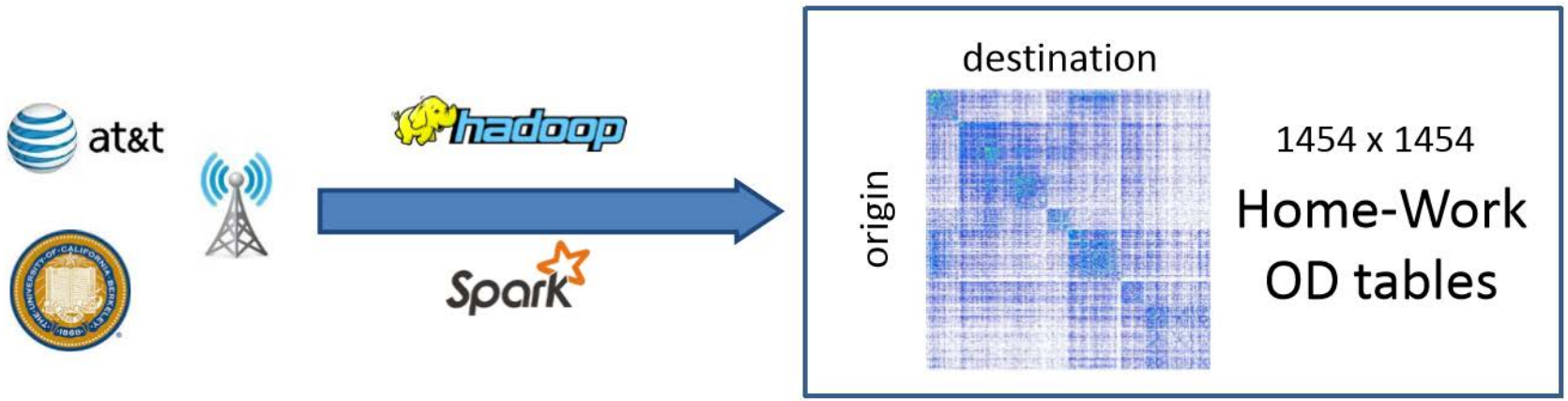


From the ground

From the vehicles

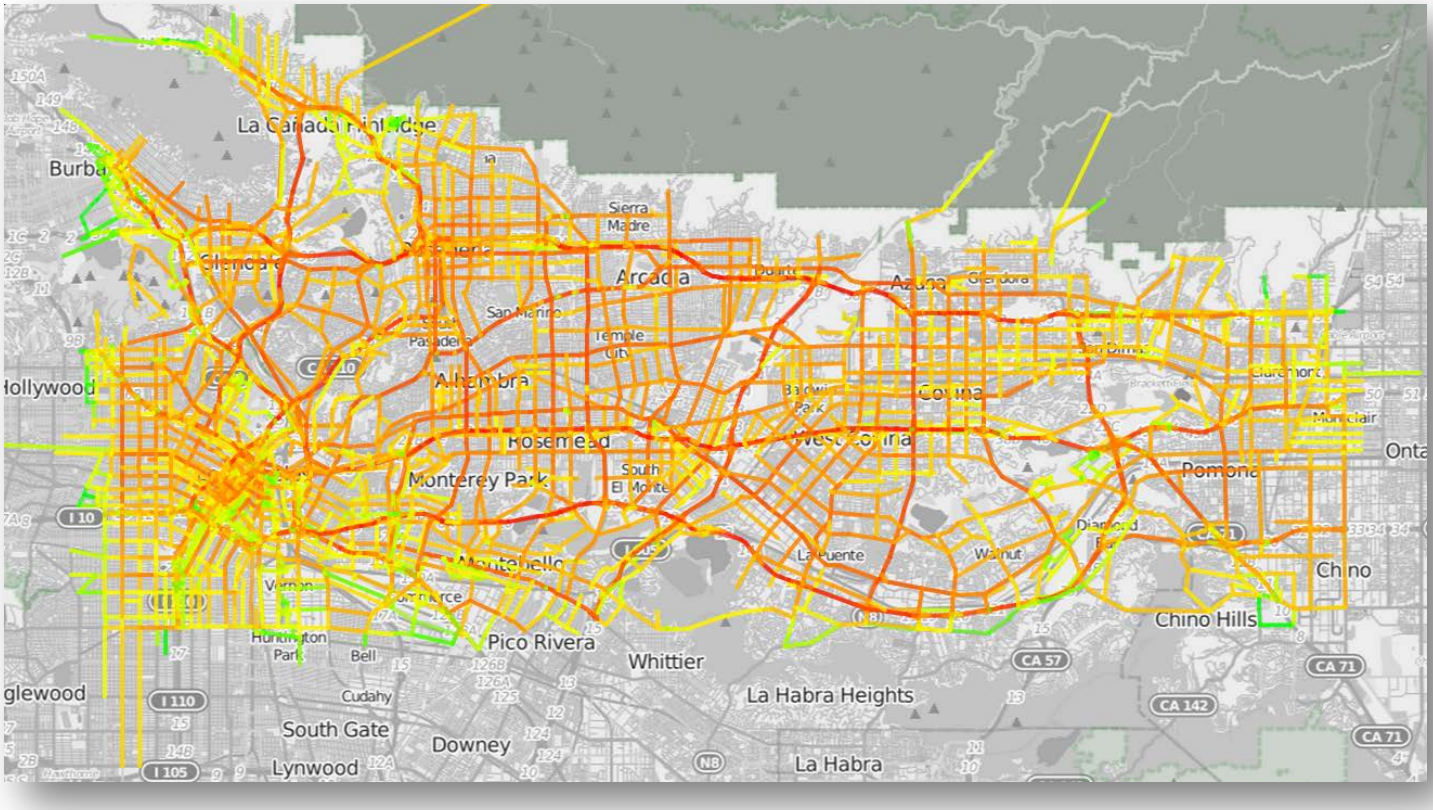
Origin/Destination data

- Problem: How to generate real time Origin Destination (OD) tables for use in traffic planning and management
- Answer – Cell towers know which phones are in their vicinity. Use this knowledge to watch the summary flow of people from one location to another during the day in real time
- UC Berkeley and AT&T are working together under the Connected Corridors umbrella to meet this challenge



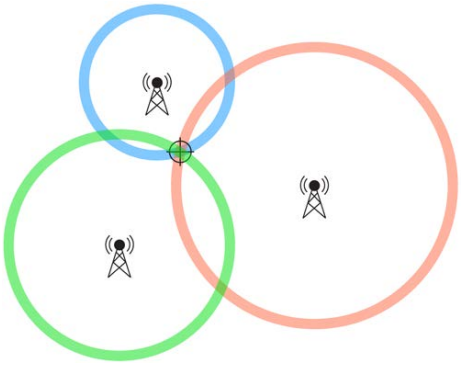
Origin/Destination data

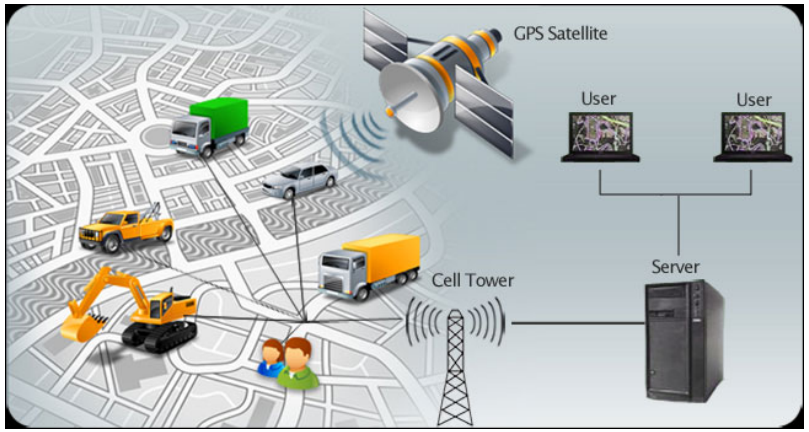
- O/D data is critical not only for real-time traffic state estimation, but also for traffic forecasts



Existing probe systems

- Current probe systems fall in three categories:
  - Cellphone-based positioning systems, which use trilateration or triangulation of cellphones to monitor traffic
  - GPS (or other positioning devices: GLONASS, Galileo…) devices relaying their data to the cellular network
  - Bluetooth-based traffic sensing



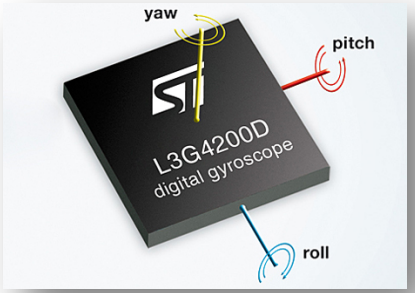


Challenges

- Cellphone-based positioning systems (GPS free) are very inaccurate in cities: from 0.1 km to 1 km
- GPS systems are much more accurate (about 10 meters in cities) BUT:
  - Sampled very infrequently (e.g. GPS tracking data for taxis is usually sampled every 30s)
  - Each sample point does not tell much about what is actually happening (congestion vs. taking a passenger?)
- Bluetooth sensors have inherent tradeoffs:
  - Close spacing between readers implies uncertain speed estimation (detection radius)
  - Extended spacing between readers implies low matching rate

Inertial Measurement Unit (IMU)-based probe data

- Inertial measurement units are devices that combine accelerometers and gyroscopes
- Accelerometers measure the proper acceleration, i.e. the acceleration w.r.t. a frame in free fall
- Gyroscopes measure the absolute rates of rotation w.r.t. an inertial frame
- Ever decreasing cost and power consumption



Comparison IMU-GPS

- About the same price (GPS slightly more expensive, ~$12/unit, IMUs ~$7/unit)
- GPS gives absolute position measurements, IMUs do not (they require position fixes using ground beacons)
- GPS is affected by canyon effect, GPS jamming or spoofing, IMUS are not
- GPS are single purpose, IMUs can be used for multiple applications (road condition monitoring, accident detection…)

IMUs in the context of traffic monitoring

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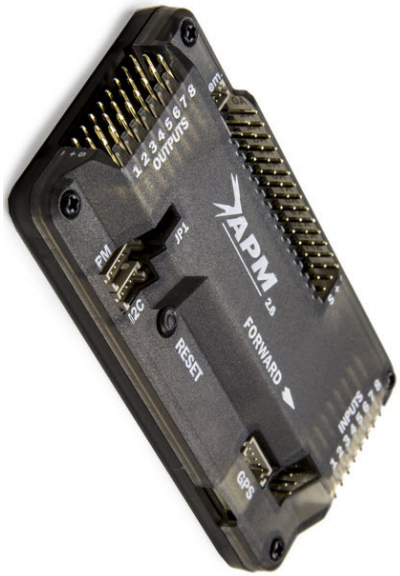
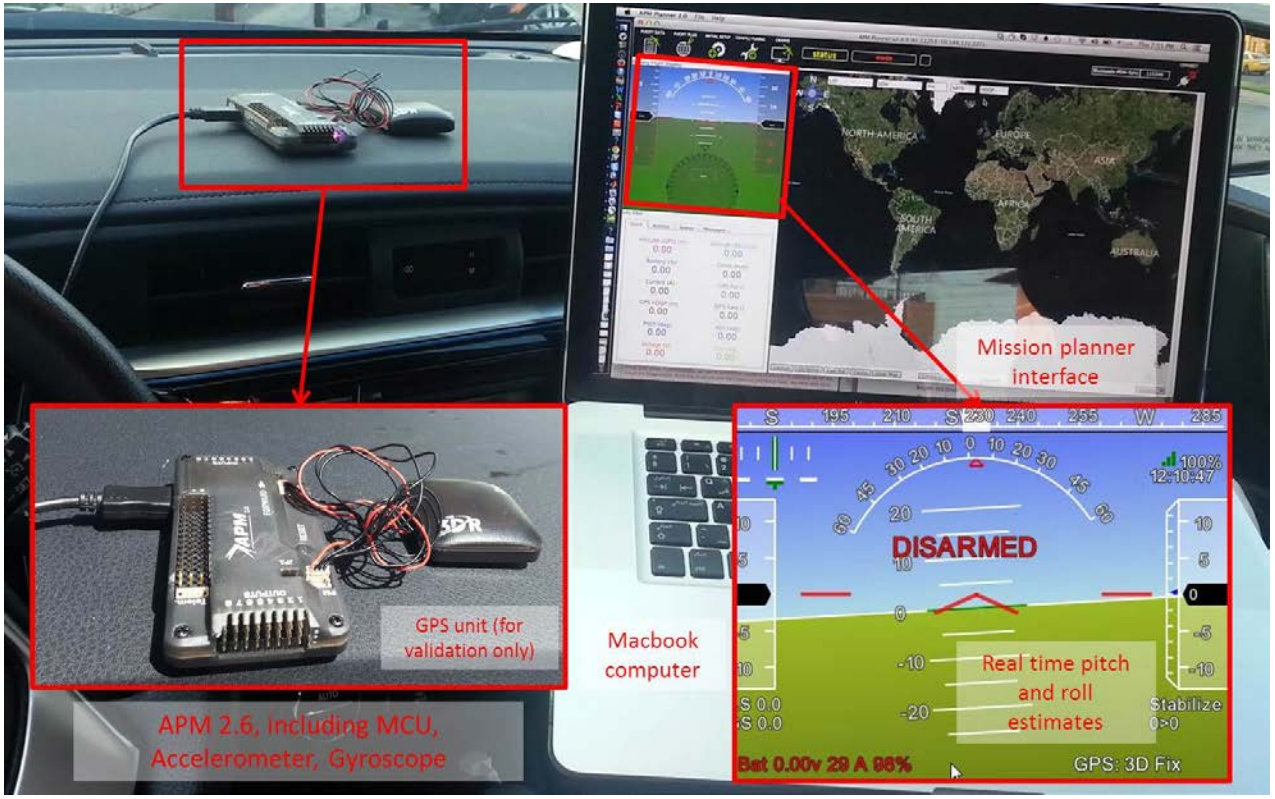
- IMUs have been used for decades in the aviation industry, in conjunction with ground beacons
- For traffic sensing applications, requires a set beacons around the locations to sense (for example CV RSE, modified Bluetooth readers)
- Road network structure can be leveraged for traffic applications.
- IMUs provide context to sensing, unlike GPSs

Validation with APM

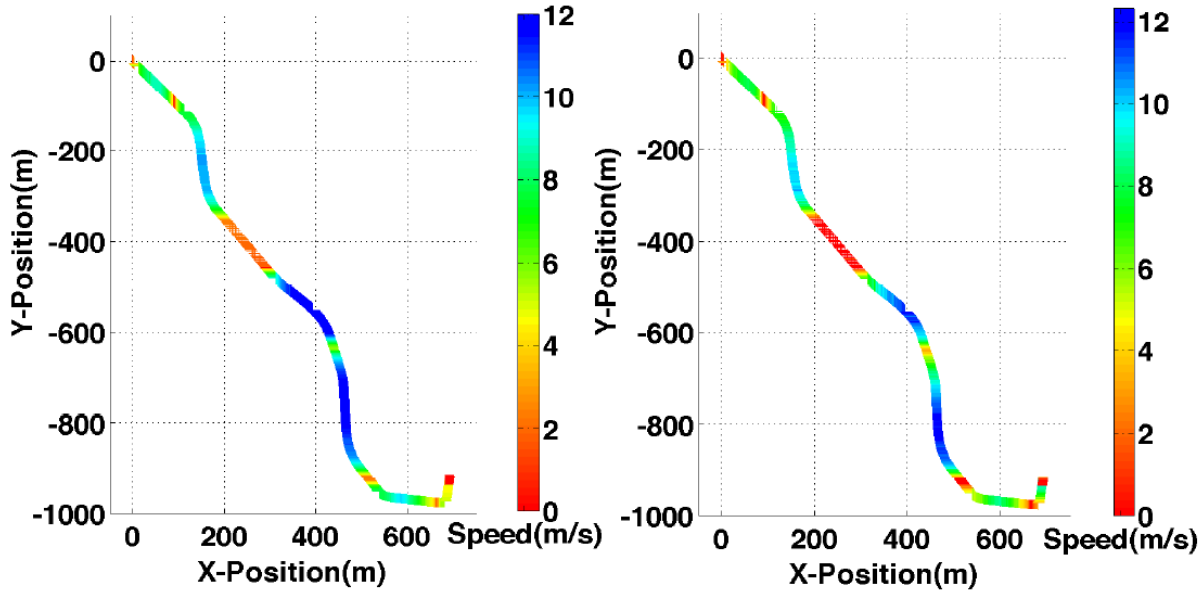
- We used a commercial Ardupilot attached to a vehicle dashboard, with a GPS module for validation





Ardupilot test

- The equipped vehicle traveled around the UT campus, storing its GPS track and computing its estimated position and speed using dead reckoning, leveraging the road network structure



Conclusion

- “Easy” upgrade to any vehicle, will be commonplace in CVs
- Not a tracking device: no privacy issues (when used in conjunction with a ground RSE network)
- Acceleration/rotation rates provide context to sensing, eliminating bad data at the source
- Other purposes: detection of incidents, accidents, road condition, skidding, road debris…

Future work

- We developed a GPS/IMU system to monitor traffic with probe vehicles, using RSE
- 200 prototypes ordered (<<$100/unit)
- Will be deployed in a heavy traffic area of Austin for high resolution traffic monitoring (lane accuracy)