
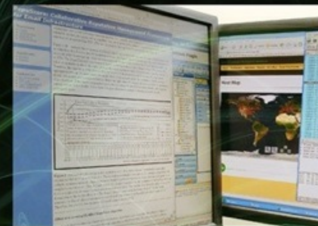


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Mobile Big Data Meets Cyber-Physical System: Mobile Crowdsensing based Cyber-Physical System for Smart Urban Traffic Control

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April 13, 2015 @ Workshop for Big Data Analytics in CPS: Enabling the Move From IoT to Real-Time Control

Outline

- Introduction
  - Urban Traffic Control and Traffic CPS
  - Mobile Crowd Sensing and Mobile Big Data
- Mobile Crowd Sensing based CPS
  - Overall System Design
  - Smartphone Sensing
  - Mobile Social Media Mining
  - Traffic Control
- Challenges of MCS based CPS
- Conclusion

Traffic Problems

- Traffic congestion in US remains stable and severe
  - Travel Time Index remained steady at 1.18
  - Fuel wasted in congested traffic reached 2.9 billion gallons
  - Total financial cost of congestion is around $121 billion

* Urban Mobility Report from Texas A&M Transportation Institute

- One effective way to solve this global problem is **smart traffic control**

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Traffic Control and CPS

- Current traffic control solutions
  - Pre-timed Control (offline with deterministic demand)
  - Semi- or Fully-actuated Control (vary in response to current demand, but with pre-defined, fixed parameters)
  - Real-time Adaptive Control (respond to dynamic and stochastic demand)
- Real-time traffic control rely on efficient monitoring
  - Monitoring/sensing + Control = CPS
  - Monitoring/sensing in dynamic urban environment is challenging

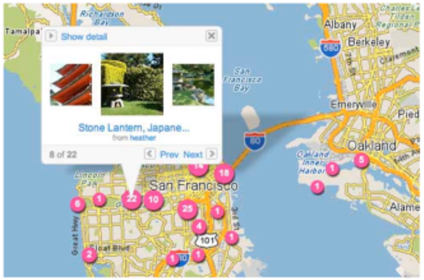
Mobile CrowdSensing

- Mobile Crowd Sensing — “Power of the crowd”
  - Individuals with sensing and computing devices collectively share data and extract information to measure and map phenomena of common interest
  - Widely used in many applications - **human as sensors**

Mobile Big Data

- Mobile sensing data from smartphones
  - GPS, gyroscope, magnetometer, accelerometer, camera, microphone, …
  - Full connected via 4G networks

- Mobile social media data
  - Facebook users share nearly 2.5 million pieces per min
  - Twitter users tweet nearly 300,000 times per min
  - Instagram users post nearly 220,000 new photos per min



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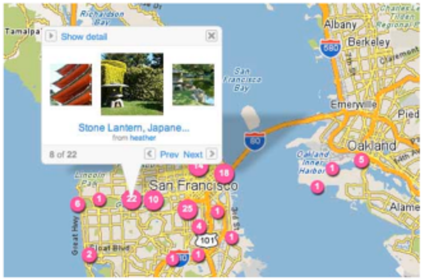

Volume, Velocity, Variety!

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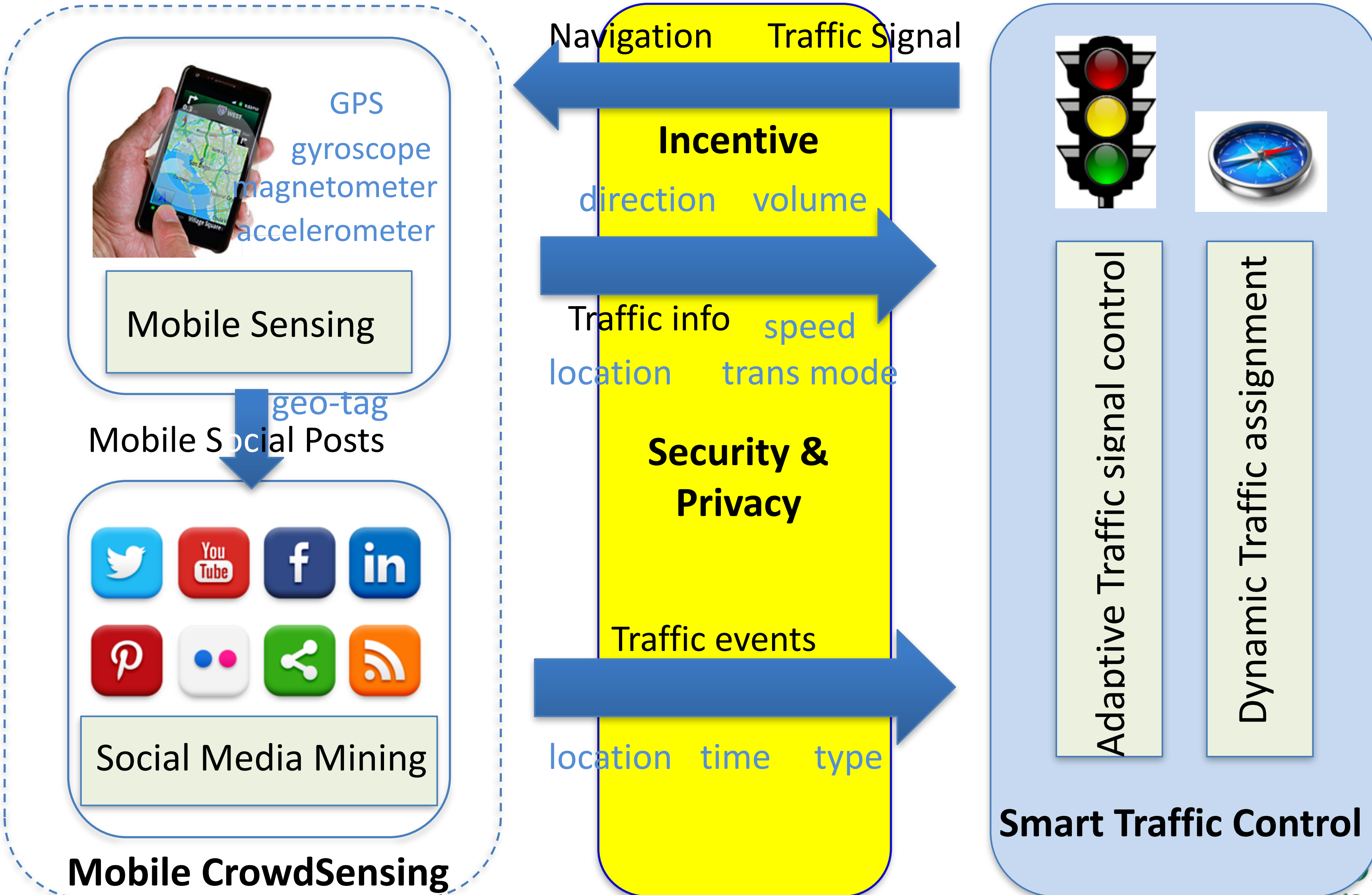
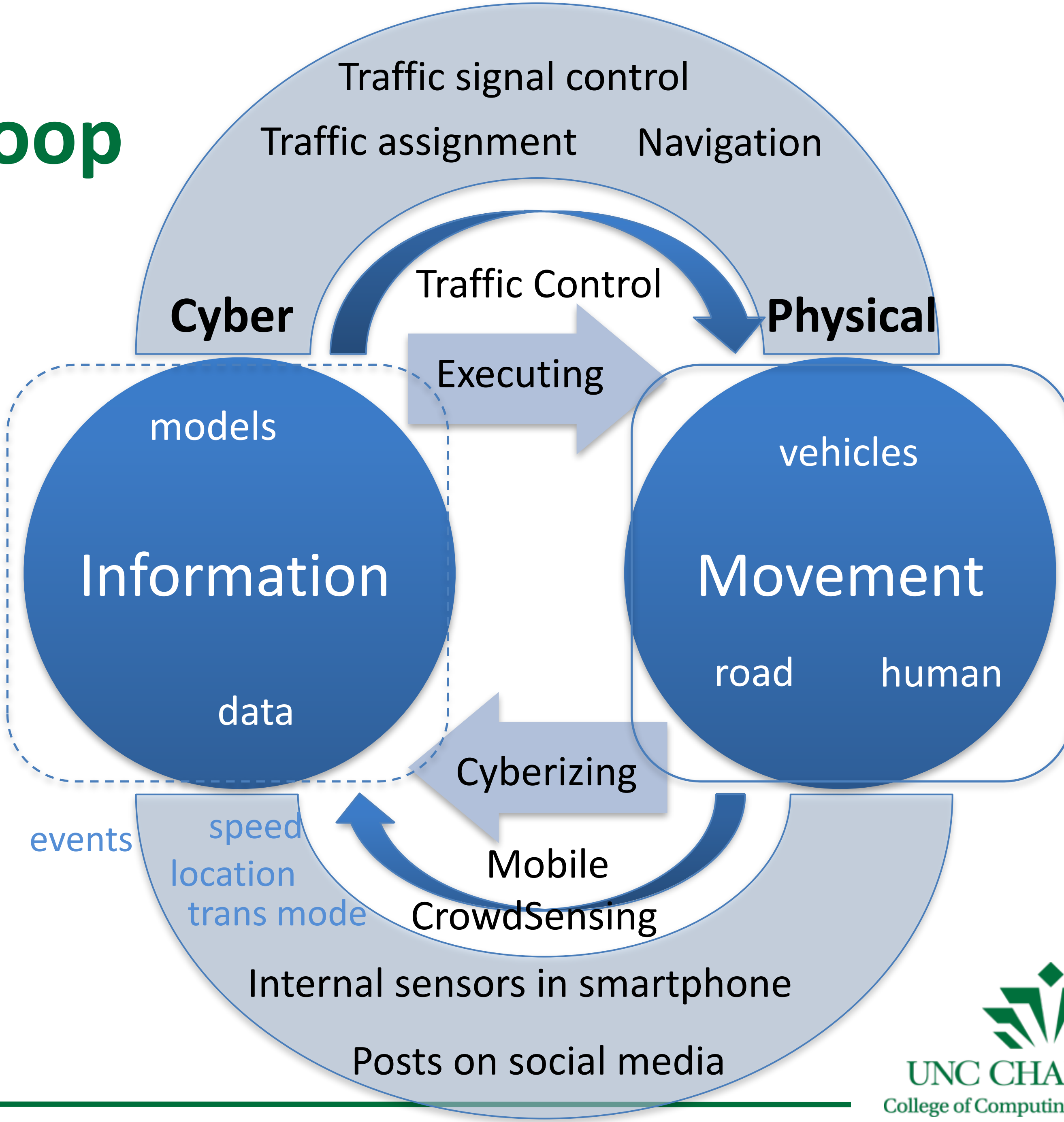
Mobile CrowdSensing based CPS



CPS Loop



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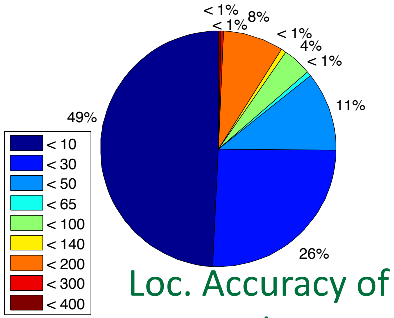
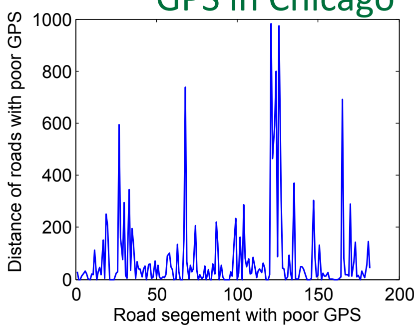
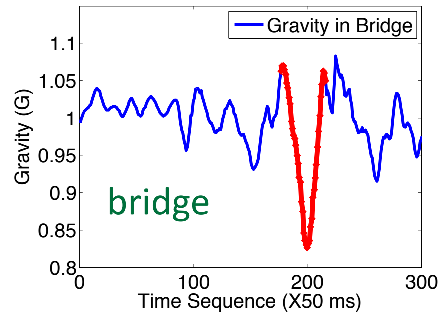
Smart Phone Sensing

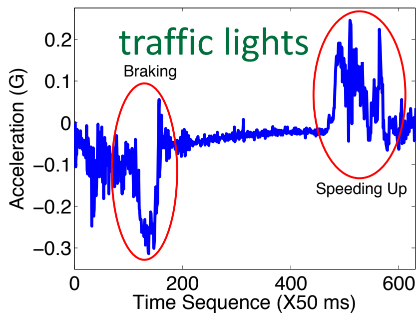
- Localization and speed estimation via sensing landmarks and driving conditions
  - self-learning trajectory estimation based on driving conditions
  - fine calibration via landmarks (e.g. bridges, traffic lights, uphill) and driving status (e.g. turns, stops)

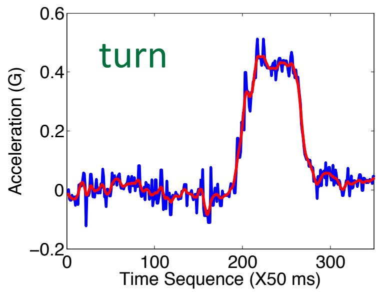


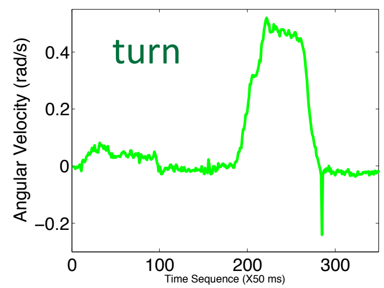
Loc. Accuracy of GPS in Chicago

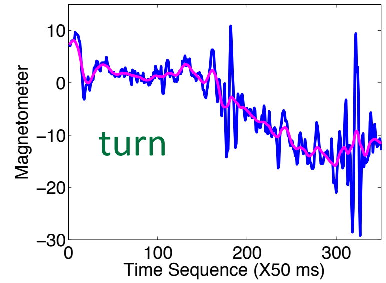








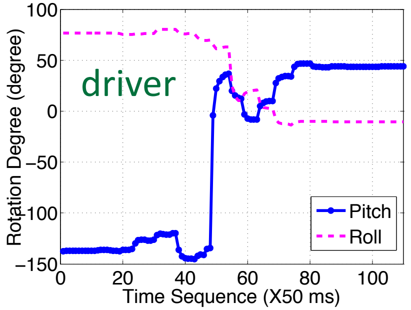


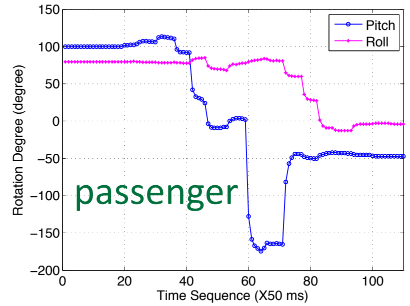


Smart Phone Sensing

- Transportation mode and driver detection via internal sensors
  - transportation mode detection via accelerometer
  - driver detection by fusing multiple evidences from inertial sensors

rotation patterns from gyroscope sensor

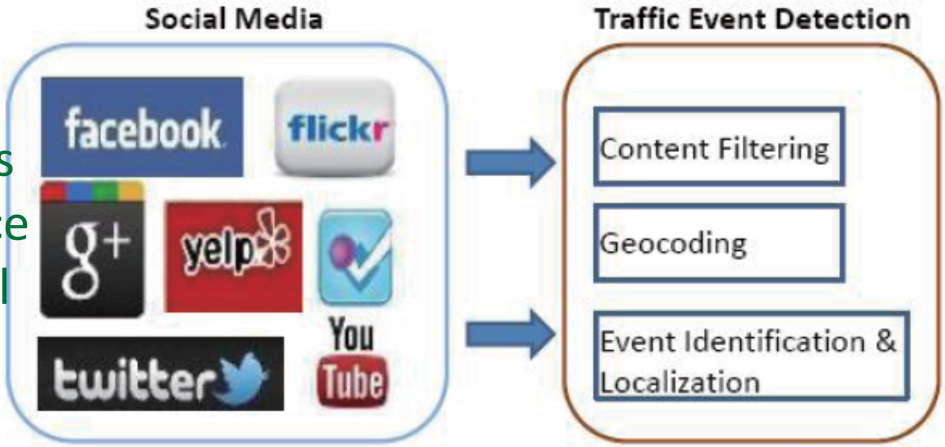




- Traffic queues and coverage monitoring via passively tracking smartphones
  - passively track smartphones via periodically WiFi messages and estimate the length of queues
  - participant selection algorithms to guarantee coverage

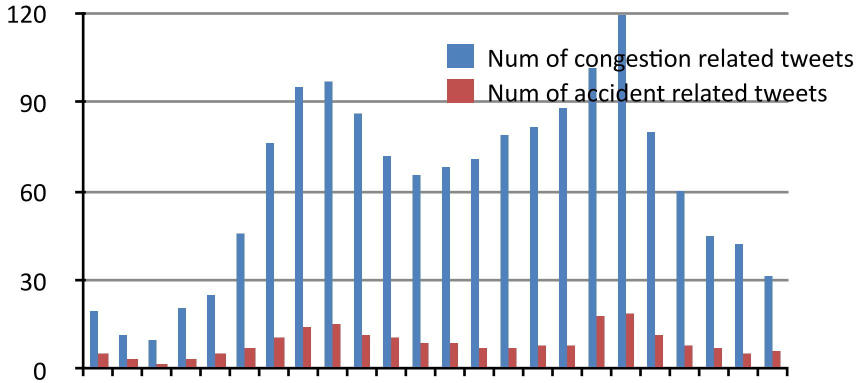
Mobile Social Media Mining

- Content filtering for traffic-related incidents
  - extract relevant content from public noisy media data via transfer learning and classification techniques
- Geocoding social media messages
  - estimate location of social media messages via extraction of fuzzy location from user profile, location information from messages themselves, and location propagation based on social ties
- Inferring and localizing traffic events
  - model all social messages and traffic-related events with a generative process, and use Gibbs sampling and Variational Inference techniques to estimate the model
  - event, time, location, probability



Chalenges in Traffic Event Mining

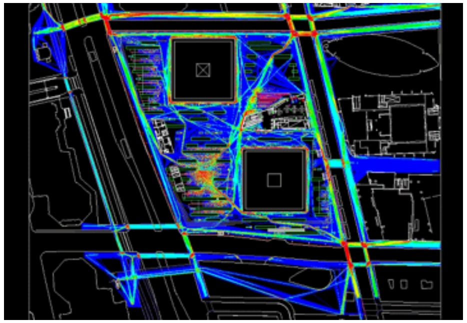
- Language ambiguity in mobile social media
  - "congestion" or "slow" may be not real
- Location ambiguity in mobile social media
  - "College Ave. traffic is so slow today"
- Event co-occurence
  - congestions may happen together with accidents
- Temporal and geographical correlations among events
  - an accident at an intersection may lead to consequent congestions on many connected roads



Hourly average frequency of tweets from 8 weeks tweets @ Washington D.C

Smart Traffic Control

- Real-time adaptive control with crowd sensing data
  - can respond to dynamic and stochastic demand
- Proposed Ideas for real-time adaptive control:
  - can be formulated as nonlinear mixed integer models
  - take the outputs of crowd sensing data (traffic information and events) into the model
  - account for the inherent stochasticity involved with crowdsensing data
  - account for the traffic flow phenomena such as queue formation and discharge, congestion build-up and dissipation, traffic holding, the well-known traffic first-in, first-out (FIFO) requirement
  - tested and validated in the simulated environments



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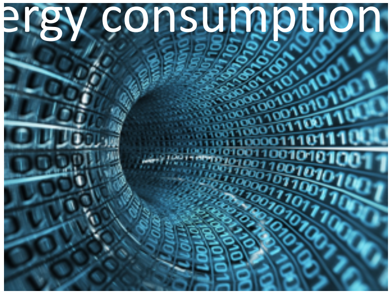
Challenges of MCS based CPS

- Data quality, redundancy, and inconsistency
  - sensing data is noisy and has various quality
  - large number of participants bring redundancy and inconsistency
- Heterogeneous, cross-space big data mining
  - mobile data from both smartphone sensors and mobile social medias
  - how to effectively mining both big data and associate them?
- Security, privacy, incentive, and energy issues
  - traffic information may be sensitive to individuals
  - anonymous participants may send incorrect or fake data
  - incentive mechanism is needed to stimulate participations
  - minimize the energy consumption

Conclusion

- New sensing paradigm, ***mobile crowd sensing***, to capture complex traffic dynamics in urban environment
- Incorporate *smartphone sensing* and *social media mining* into a large-scale transportation CPS for *smart traffic control*
- Shed important light on the methodology to design a general MCS based CPS
  - how to handle massive and noisy sensed data from crowd
  - how to motivate users to contribute data
  - how to leverage the power of crowd
  - how to play tradeoff among sensing quality, efficiency, energy, security, and privacy

Thank You!

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