Outline

• Next generation mobility systems
• Engineering challenges of the future
• Recent advancements
Next Generation Mobility Systems

- IOT: travelers, vehicles, infrastructure are increasingly equipped with sensors
- Rise in connectivity (V2V, V2I): increasingly intricate systems
- Empowering data
  - Travelers have a better understanding of their travel alternatives
  - They are becoming real-time optimizers of their trips

Shapes the systems of the future:

1. User-centric
2. Sustainable
3. Quickly evolving
Next Generation Mobility Systems

1. User-centric: the unique on-demand needs and preferences of each traveler will be at their core

2. Sustainable
   - Major contributor to fuel consumption and greenhouse gas emissions
   - Pressing necessity to mitigate the impacts of congestion: energy, environment, economy, society
3. Quickly evolving

- Big data era has welcomed new stakeholders into the sector
- Their disruptive innovations have allowed the system to evolve at an unprecedented fast pace
Next Generation Mobility Systems

1. User-centric
2. Sustainable
3. Quickly evolving

Use high-resolution data to:
1. Formulate models
2. Calibrate models
3. Use models to inform the design of mobility systems
1. Formulate Models

- Improve our understanding of:
  - traveler behavior: how individuals make, and revise, travel decisions
  - the interaction of travelers, vehicles and the infrastructure
- Adapt transportation system
- Influence behavior

- Goulet Langlois, Koutsopoulos and Zhao (2016)
- TfL smart card data used to infer users travel patterns
- Identified clusters of travel and activity patterns
- Studied how short-term travel choices relate to long-term elements of lifestyle as captured from socio-demographic characteristics
2. Calibrate Models

- Replicate observed travel patterns
- Berlin Metropolitan Area
- Over 24,000 links; 11,000 nodes and 172,000 trips
- Poster!

Zhang, Osorio, Flötteröd (2015, 2016)
Next Generation Mobility Systems

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Transportation Modeling Paradigms

- Macro
- Meso
- Micro

Detail vs. Tractability/Optimization

Macroscopic, Mesoscopic, Microscopic
High-resolution Models
Simulation-based Optimization

- Computationally inefficient, stochastic, no closed-form available for optimization
- Efficiency is critical for transportation practice
- Current algorithms:
  - Black-box approach, asymptotic properties, not efficient

How can inefficient simulators be used efficiently for optimization?

- Embed analytical structural information in the algorithm
- Derive structure from analytical models
- Use of efficient analytical models: differentiable, scalable
- Transcend the use of a single modeling paradigm
Accounting For Intricate Behavior

- New York City
- Critical area: Queensboro Bridge
- Traffic signal control
- Intricate traffic dynamics: highly congested, multi-modal, pedestrian traffic, grid topology, short links, intricate travel behavior
New York City

- Morning-peak period
- 134 Roads, 41 intersections
- An average of over 11,000 trips

Improvements of:
- average trip travel time by 10%
- average queue-length by 28%
- spillback probabilities by 23%
- average throughput by 2%
- Traffic-responsive signal control

Osorio et al. (2014) *Proc. ISTS*
New York City

- We can account for intricate behavior for optimization
- There is great room for improvement to mitigate congestion with minimal investment

Osorio et al. (2014) *Proc. ISTS*
Pushing the frontiers of large-scale control

- 924 links, 2600 lanes, 28000 trips
- Control 96 intersections
- Simulation budget of 50 runs
- NYCDOT signal plan: average link density

How did we do this?
Learning about problem structure
Large-scale Optimization

- 603 links, 231 intersections, 12400 trips
- City-wide signal control: 17 intersections
- What can be done with only 150 simulation runs?

What do travelers care about?

- With big data we can rethink how we evaluate network performance
- Reliable and robust networks
- Travel time reliability is important in route and mode choice
- Enhancing network reliability is a critical goal of major transportation agencies
- Osorio, Chen and Santos (2012) *Proc. INSTR*

- Sustainable networks
- Use of instantaneous vehicle performance
Integrated on-demand mobility services

- On-demand vehicle-sharing
- Integrated systems
  - How can we complement the existing road and transit network?
  - City of Boston
  - Improving both utilization, revenue and accessibility
Ongoing Work

- Real-time high-resolution control
- Demand management: real-time congestion pricing
- Algorithms for autonomous and mixed vehicle fleets

Bailey, Osorio Antunes and Vasconcelos (2015) *Proc. Mobil.TUM*
Enable the use of high-resolution models, formulated at the scale of individual travelers, to optimize urban networks at the scale of full cities or regions
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