Future of AI in Transportation

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Outline

• Part 1: Why AI and why now?
• Part 2: What is AI good for?
• Part 3: Why AI instead of other methods?
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Complexities compound transportation issues today

- Connectivity and automation (smartphones, CAVs, 5G)
- Technology-enabled business models (TNCs, routing apps, micromobility)
- Climate change (extreme weather, supply chain disruptions)
- International affairs (trade disputes)
Critical Issues in Transportation 2019

9 of 12 critical issues exacerbated by growing complexity of transportation systems.

1. Transformational Technologies and Services: Steering the Technology Revolution
2. Serving a Growing and Shifting Population
3. Energy and Sustainability: Protecting the Planet
4. Resilience and Security: Preparing for Threats
5. Safety and Public Health: Safeguarding the Public
6. Equity: Serving the Disadvantaged
7. Governance: Managing Our Systems
8. System Performance and Management: Improving the Performance of Transportation Networks
9. Funding and Finance: Paying the Tab
10. Goods Movement: Moving Freight
11. Institutional and Workforce Capacity: Providing a Capable and Diverse Workforce
12. Research and Innovation: Preparing for the Future
Why AI and why now?

*AI can help overcome complexity.*

- Change is outpacing existing methodology for reliable transportation systems.
- Opportunity in data: all this complexity is increasingly captured (sensors, smartphones).
- Strength of AI, especially modern deep learning: extracting useful information out of a sea of data.

Image credit: PCMag
Outline

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Challenge: safety

AI to leverage the complexity to identify unsafe events

Application
- Pedestrian safety systems
- In-vehicle safety systems
- Failures of infrastructure, vehicles, equipment

AI solution
- Predict potential accidents
- Context-aware technology
- Prediction of failures, automated inspections
Challenge: congestion

AI to manage the complexity and coordinate supply and demand

Application
- Synchronized modalities (MoD, bus, train, subway, bike)
- MoD curb-side management
- Demand and mode shift
- Advanced load balancing, scheduling, and vehicle right-sizing based on preferences
- AVs for traffic smoothing

AI solution
- Demand prediction
- Activity recommendation
- Personalization and preference inference
- Automatically learn vehicle controllers
Emerging and cross-cutting

AI to transcend complexity and evolve the transportation system

Application

• Impact assessment (new modes, regulations and pricing schemes, business models)
• Coordination among city functions (transportation, maintenance/works, energy, water, waste)
• Freight + AI
• Immobility solutions (virtual presence, augmented/virtual reality (AR/VR), telecommuting, co-working)

AI solution

• Learned recommendations of rules and regulations
• Holistic prediction of city demands
• Predict what people want to buy
• Synthetic avatars
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CAVs for congestion mitigation

What is the potential impact on traffic congestion of automating a fraction of vehicles?
Focus: impact of vehicle kinematics
Traffic jams

Partial differential equations (PDE)

Setting: 22 human drivers

Instructions: drive at 19 mph.

No traffic lights, stop signs, lane changes.

Sugiyama, et al.

1955

900 papers on PDEs for traffic

2008

2019
Traffic jams

Partial differential equations (PDE)

Setting: 22 human drivers

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Traffic jams still form.

Sugiyama, et al.

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Video credits: NewScientist.com
Mixed autonomy traffic

Partial differential equations (PDE)

Setting: 22 human drivers

Instructions: drive at 19 mph.

No traffic lights, stop signs, lane changes.

Traffic jams still form.
Deep reinforcement learning (RL)

Decisions in urban systems:
- Vehicle accelerations
- Tactical maneuvers
- Transit schedules
- Traffic lights
- Land use
- Parking
- Tolling

Goal:
Learn policy (decision rule) to maximize long-term reward

Deep RL: methods to optimize a policy (a deep neural network) to maximize long-term reward in complex sequential decision problems.

Global rewards:
- Average velocity
- Energy consumption
- Travel time
- Safety, comfort

Reward functions:
- DQN (2015)
- TRPO (2015)
- AlphaGo (2016)
Mixed autonomy traffic (AI solution)

Setting: 1 AV, 21 human

Experiment
• Goal: maximize average velocity
• Observation: relative vel and headway
• Action: acceleration
• Policy: multi-layer perceptron (MLP)
• Learning algorithm: policy gradient

Results
• 1 AV: +49% average velocity
• First near-optimal controller for single-lane
• Uniform flow at near-optimal velocity
• Generalizes to out-of-distribution densities

Instructions: follow the vehicle in front, and close gaps. No tail-gaiting!

AV: Hand-tuned model-based controller (PI saturation)

Traffic jams diminished.

1 AV: +14% average velocity (vs. 49%)
AI + Traffic LEGO blocks
Benchmarks for autonomy in transportation

Wu, et al. 2017

5-10% AVs

Sugiyama, et al. 2008

2019

1955
Single-lane
+49%
Straight highway

Multi-lane
+30%

Bottleneck

On/off-ramp
+142%

Grid network
+25%

Intersection
+60%

Signalized intersection

Wu, et al. 2017
**RL + increasing complexity** *(current work)*

**Setting:** No AVs, 100% IDM

**Setting:** 10% AVs, 90% IDM

**Phenomenon:** capacity drop

- 1480 veh/hr
- 1800 veh/hr

**Results:**
- 25% improvement
- Avoids capacity drop
- Learned policy transfers to different inflow rates, number of lanes, and percent of autonomous vehicles

**Successful transfer:**
- Network: 8 > 4 > 2 Bottleneck
- Network: 8 > 4 > 2 > 1 Bottleneck

Scenario: varying inflow rates, varying % AVs.
Where we are, where next?

- **Key idea**: AI has the potential to keep pace with increase in complexity.
- **Research challenge**: Is there a limit for the level of complexity that AI can handle?
- **Relies on access to data**, which is increasingly privatized.

Full-scale regional network

San Francisco Bay Bridge

San Francisco Downtown

Physical deployment

Insights for transportation planning
Collaborators & Partners

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PATH
New lab!

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Future of AI in transportation

Main message:
• Critical issues in transportation are exacerbated by growing complexity and increasing pace of change in the world.
• There is an opportunity to overcome these challenges by developing AI to leverage, manage, and transcend complexity and evolve our transportation systems.

Takeaways:
• Strong potential for AI in future solutions in safety, congestion, and emerging and cross-cutting applications.
• AI-based solutions may have a chance at keeping up with the pace of change in the world. Requires further investigation.
• AI-based solutions rely on access to increasingly privatized data.