Future of AI in Transportation

Cathy Wu | Assistant Professor

LIDS, CEE, IDSS

TRB Executive Committee, Policy Session on AI in Transportation, 2020

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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- **Part 1: Why AI and why now?**
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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.

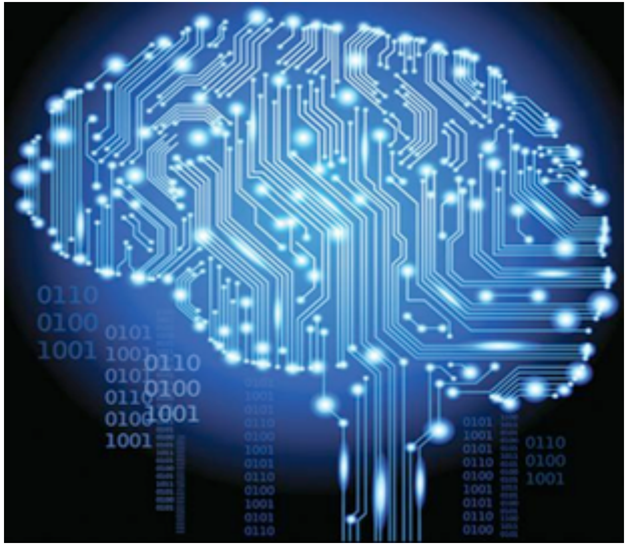

Image credit: PCMag

Outline

- Part 1: Why AI and why now?
- **Part 2: What is AI good for?**
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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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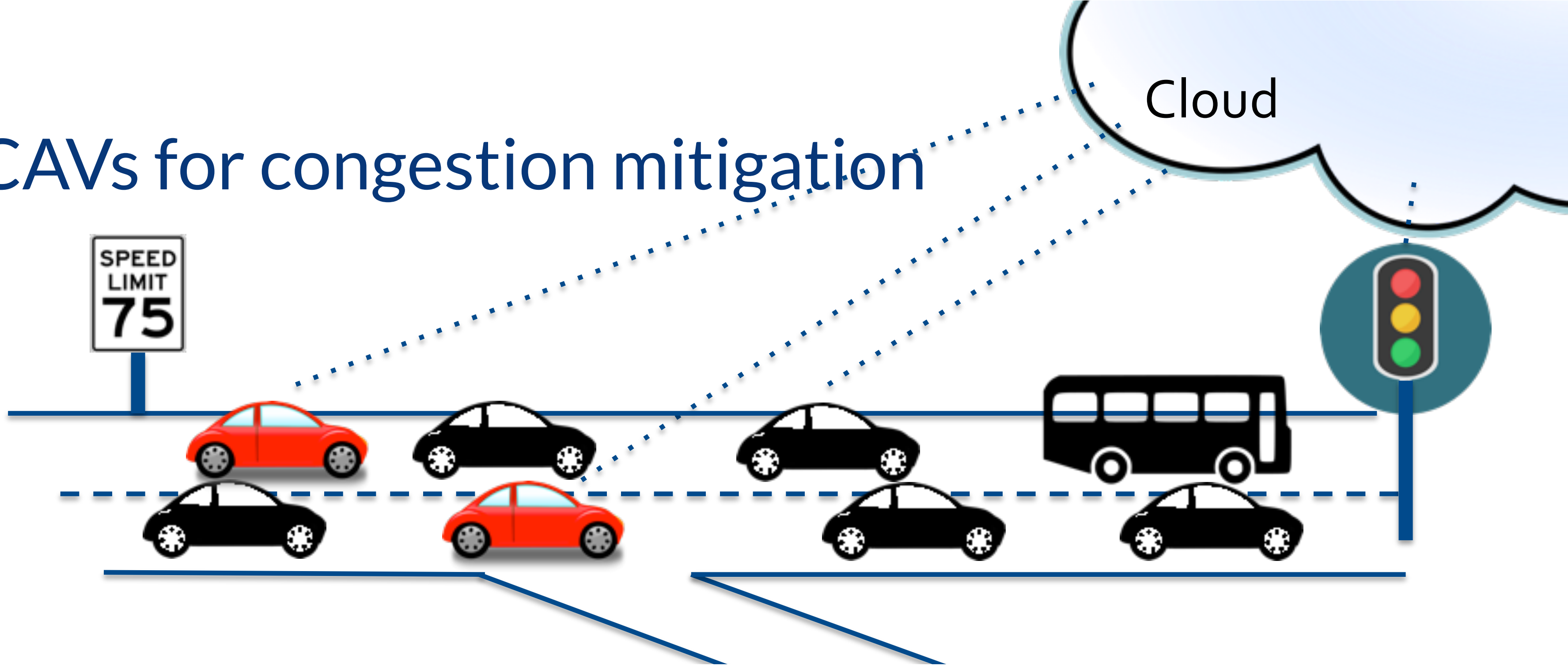
CAVs for congestion mitigation



What is the potential impact on traffic congestion of automating a fraction of vehicles?

Focus: impact of vehicle kinematics

Traffic jams

Sugiyama, et al.

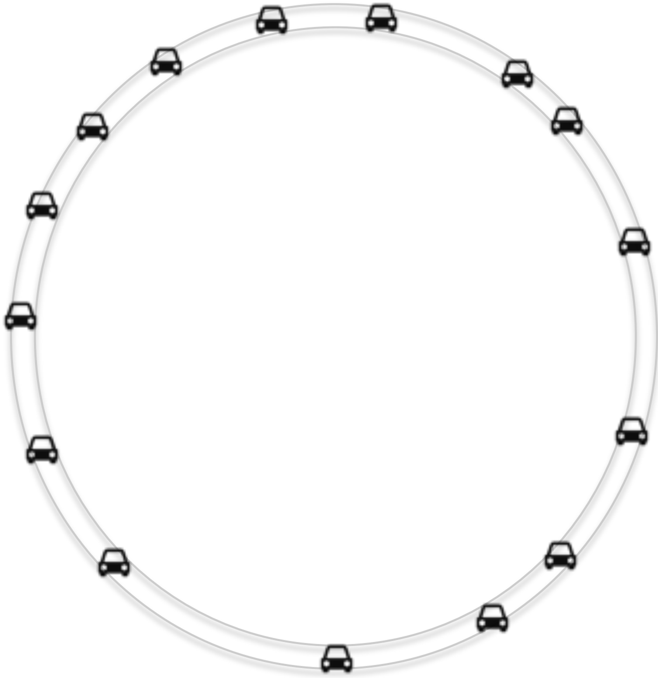
1955 — 900 papers on PDEs for traffic — **2008** — 2019

Partial differential equations (PDE)

Setting: 22 human drivers

Instructions: drive at 19 mph.

No traffic lights, stop signs, lane changes.



Traffic jams

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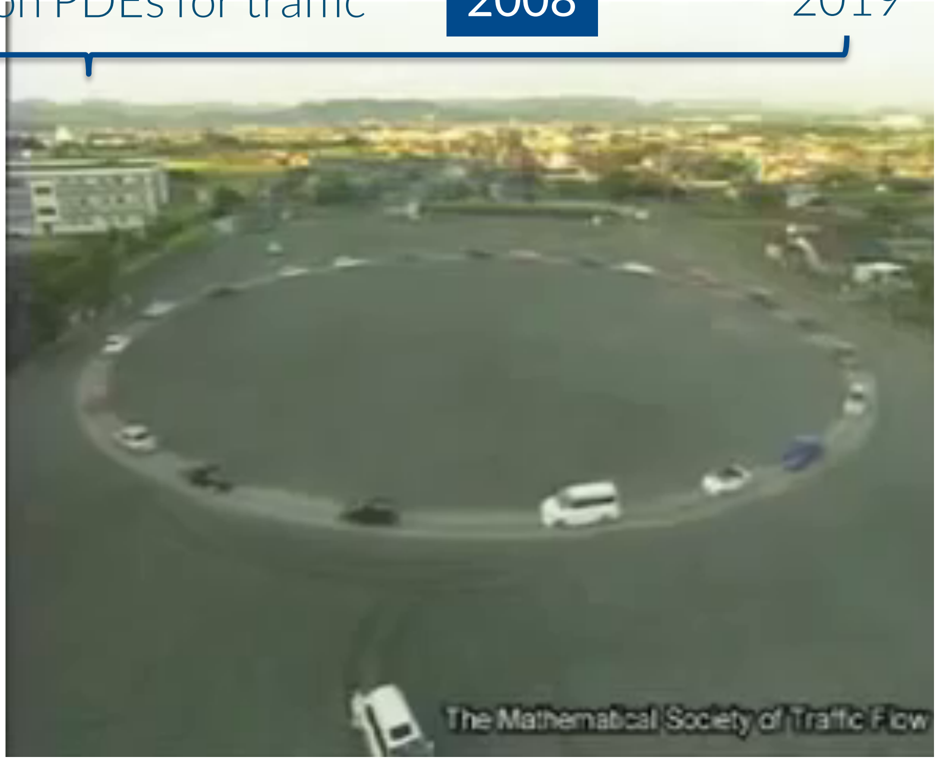

Video credits: NewScientist.com

Mixed autonomy traffic

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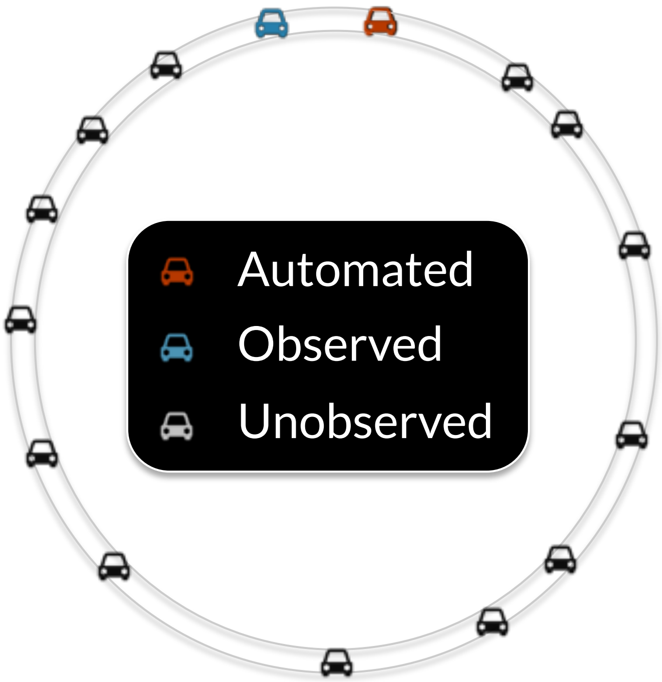
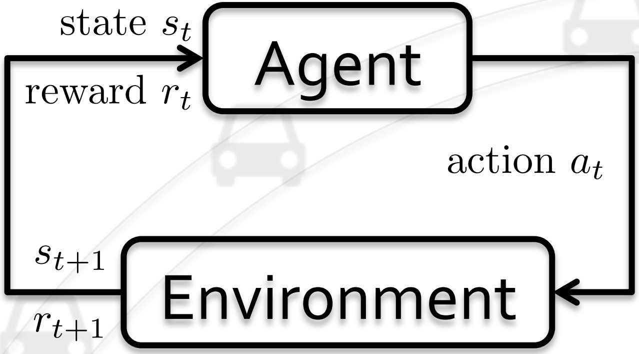


Deep reinforcement learning (RL)



Decisions in urban systems:

Vehicle accelerations
Tactical maneuvers
Transit schedules
Traffic lights
Land use
Parking
Tolling
...

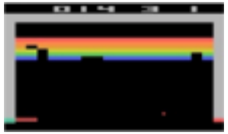
Goal:

learn policy (decision rule)
to maximize long-term reward

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

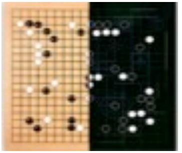
Global rewards

Average velocity
Energy consumption
Travel time
Safety, comfort



DQN (2015)

TRPO (2015)



AlphaGo (2016)

Mixed autonomy traffic (AI solution)

Wu, et al. 2017

1955 — Sugiyama, et al. 2008 — 2019

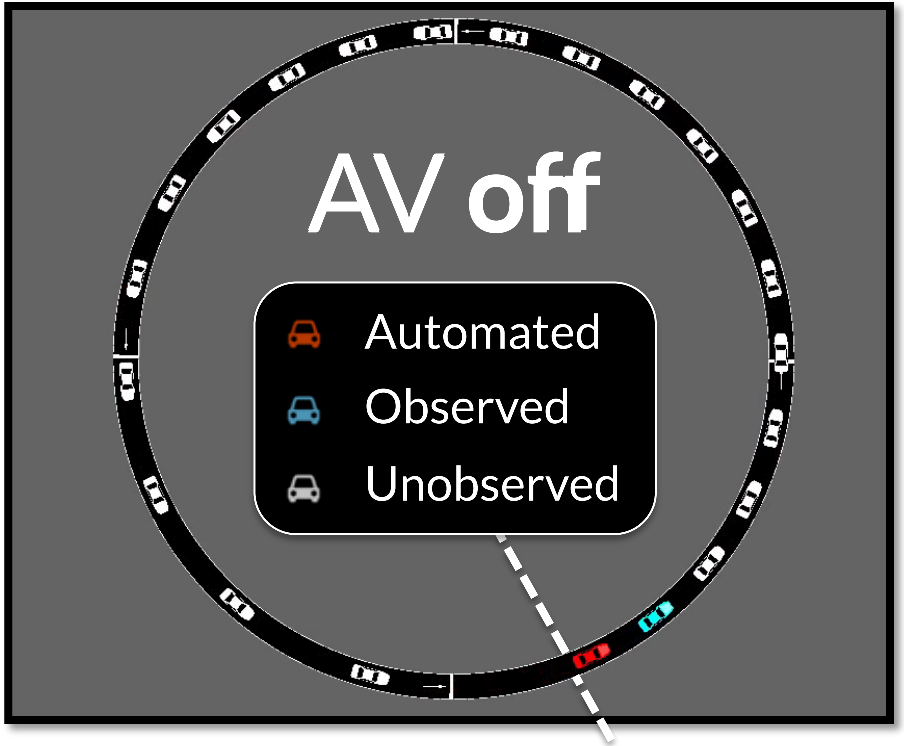
Setting: 1 AV, 21 human

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



Wu, et al. CoRL, 2017; **Wu**, et al. IEEE T-RO, in review.

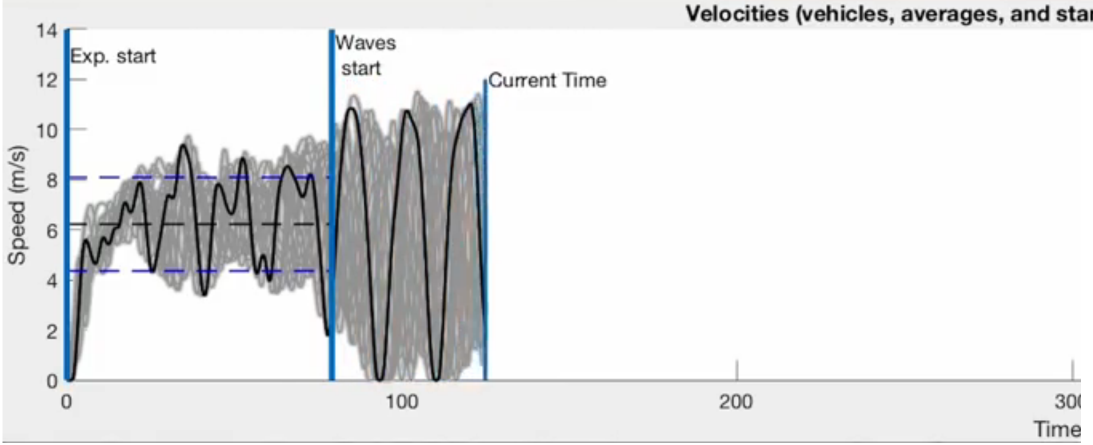
Mixed autonomy traffic (non-AI solution)

Stern, et al.
2017

1955

Sugiyama, et al. 2008

2019



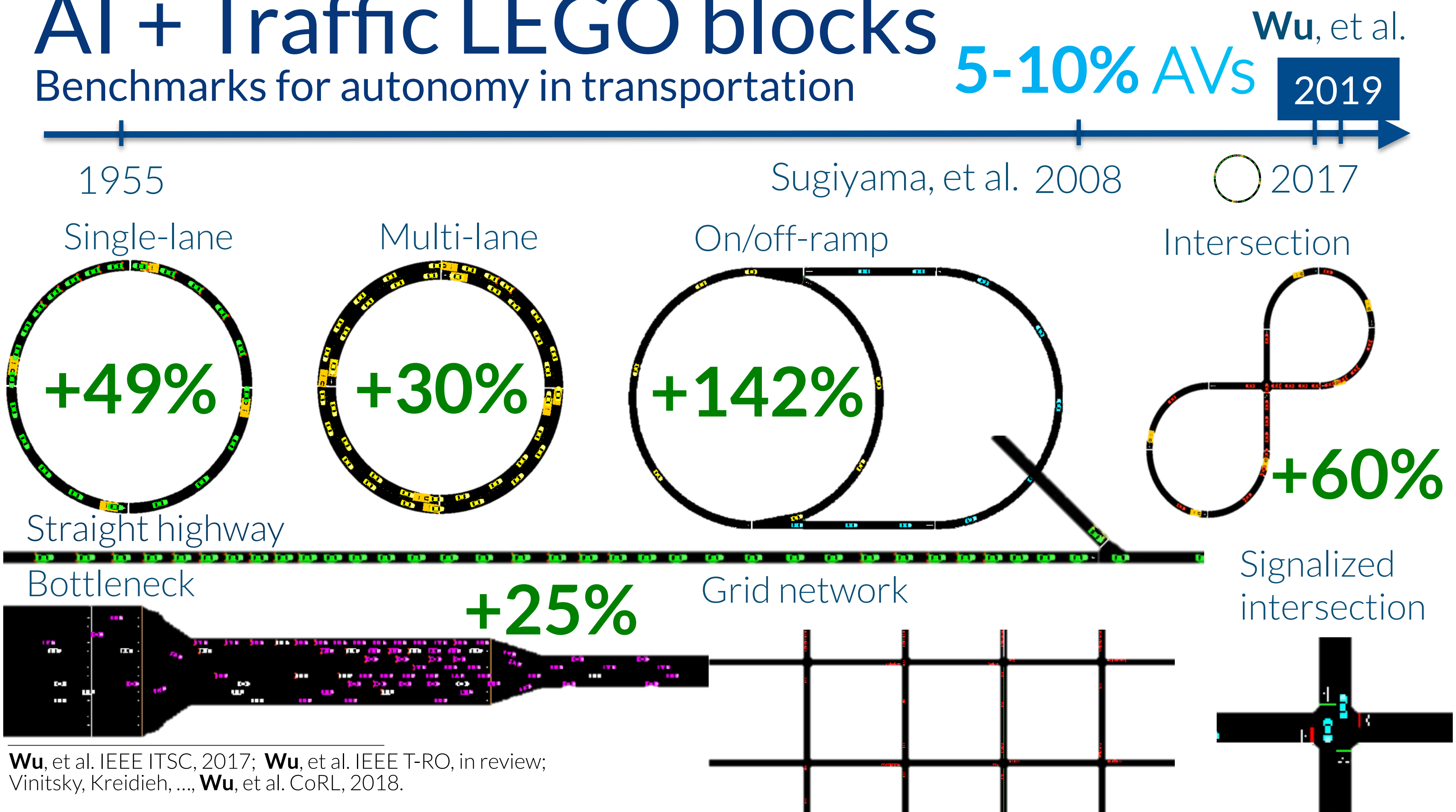
Instructions: follow the vehicle in front, and close gaps. No tail-gaiting!

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

Traffic jams diminished.
1 AV: **+14%** average velocity (vs. 49%)

AI + Traffic LEGO blocks

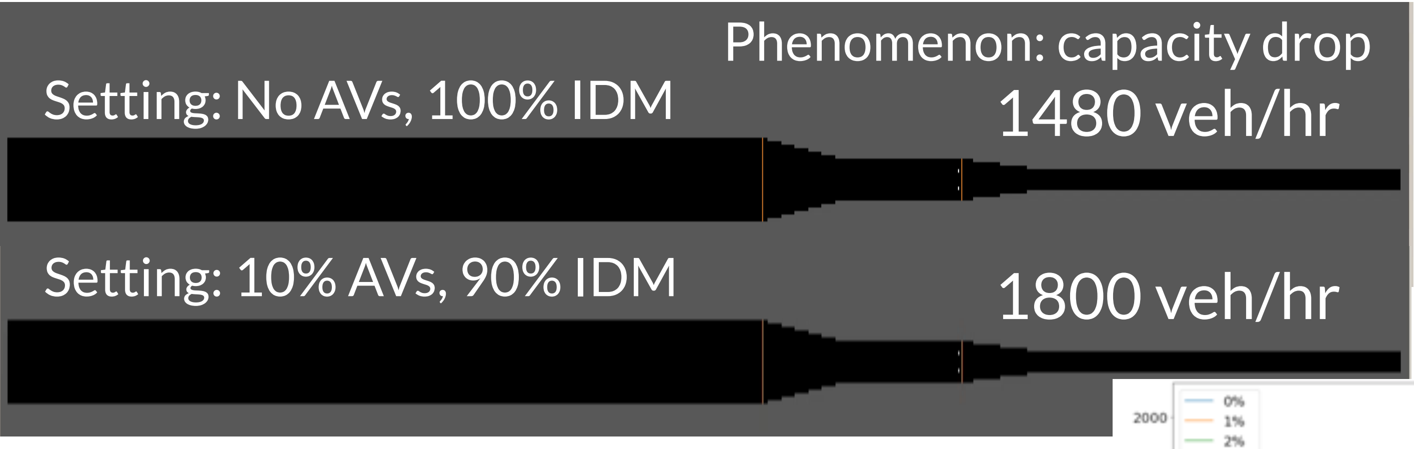
Benchmarks for autonomy in transportation



Wu, et al. IEEE ITSC, 2017; **Wu**, et al. IEEE T-RO, in review;
Vinitsky, Kreidieh, …, **Wu**, et al. CoRL, 2018.

RL + increasing complexity (current work)

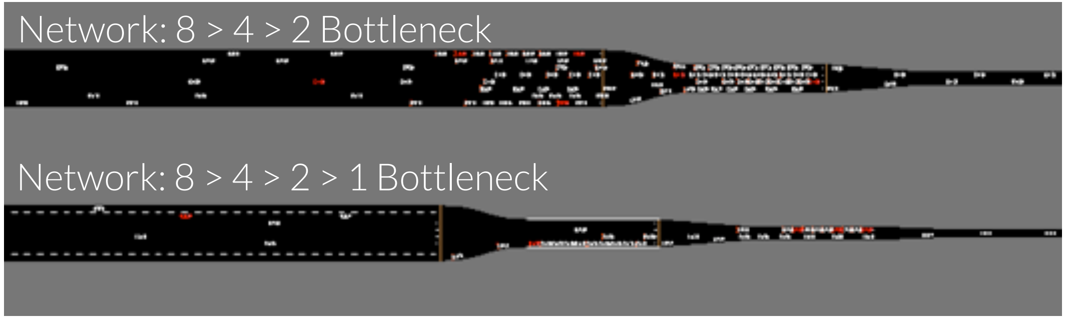
Zhongxia Yan

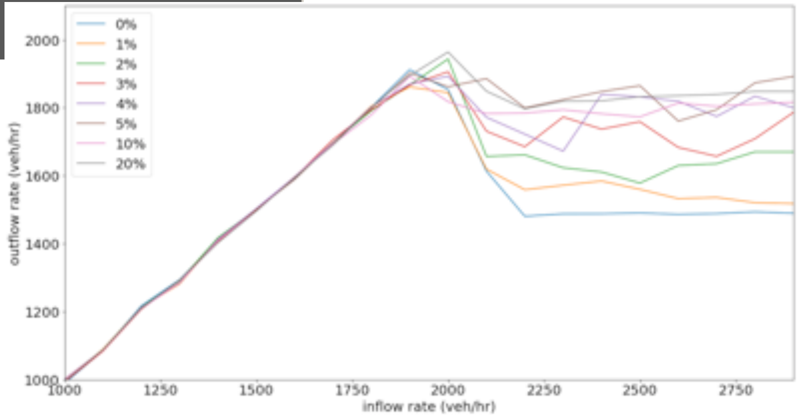


Results:

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

Successful transfer:





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

Physical deployment

Insights for transportation planning

Collaborators & Partners


Alexandre Bayen
Berkeley

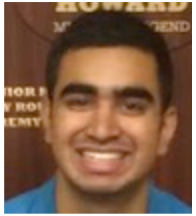

Eugene Vinitsky
Berkeley

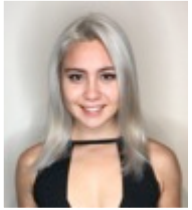

Aboudy Kreidieh
Berkeley


Kanaad Parvate
Berkeley


Zhongxia Yan
MIT


Kathy Jang
Berkeley


Nishant Kheterpal
Berkeley

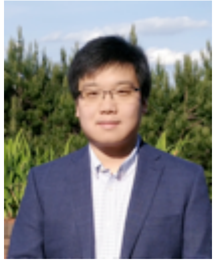

Leah Dickstein
Berkeley


Ananth Kuchibhotla
Berkeley


Nathan Mandi
Berkeley

NSF
FLOW
Microsoft
aws
OpenAI
riselab UC Berkeley
Berkeley DeepDrive
BAIR
BERKELEY ARTIFICIAL INTELLIGENCE RESEARCH
CALIFORNIA PATH

New lab!



Weizi Li
Postdoc

Zhongxia Yan
PhD student

Vindula Jayawardana
PhD student

NARLabs 財團法人國家實驗研究院
NCHC 國家高速網路與計算中心
National Center for High-performance Computing

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MIT

IDSS
MIT INSTITUTE FOR DATA, SYSTEMS, AND SOCIETY

LIDS
LABORATORY FOR INFORMATION AND DECISION SYSTEMS
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Civil and Environmental Engineering

cathywu@mit.edu

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.