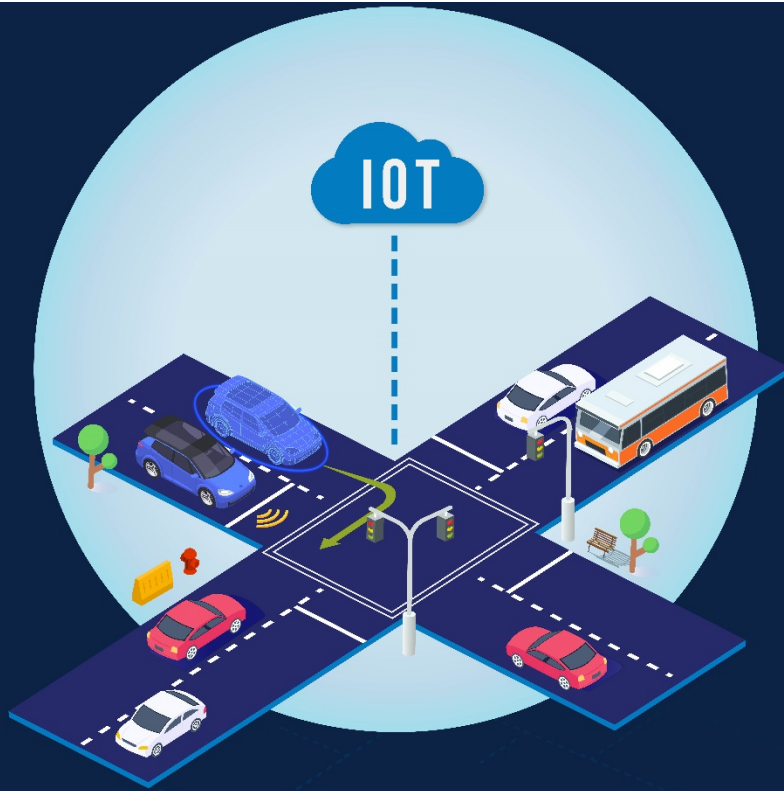


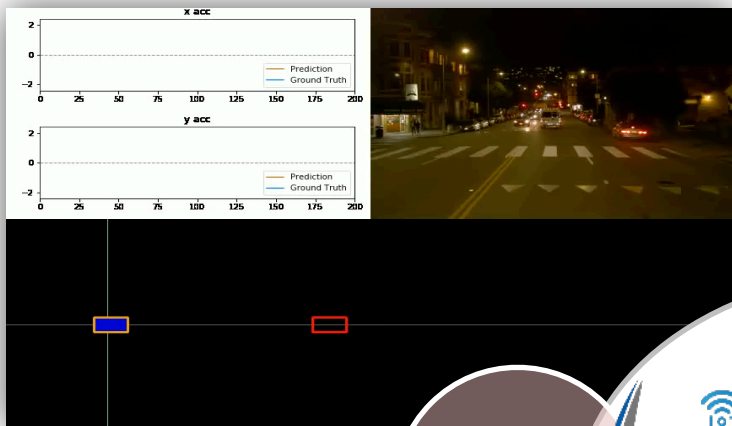
Research Gaps and Fundamentals Of Transportation Digital Twins: Hybrid Twin Leveraging the COSMOS Testbed

Sharon Di
Columbia University



DIGITAL
TWIN

Waymo Imitation Learning



Subway Crowd Management to Minimize Airborne Transmission of Respiratory Viruses



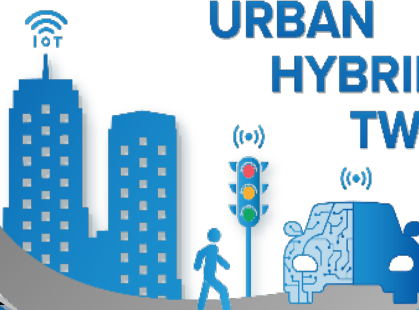
Tech



AI



URBAN HYBRID TWIN

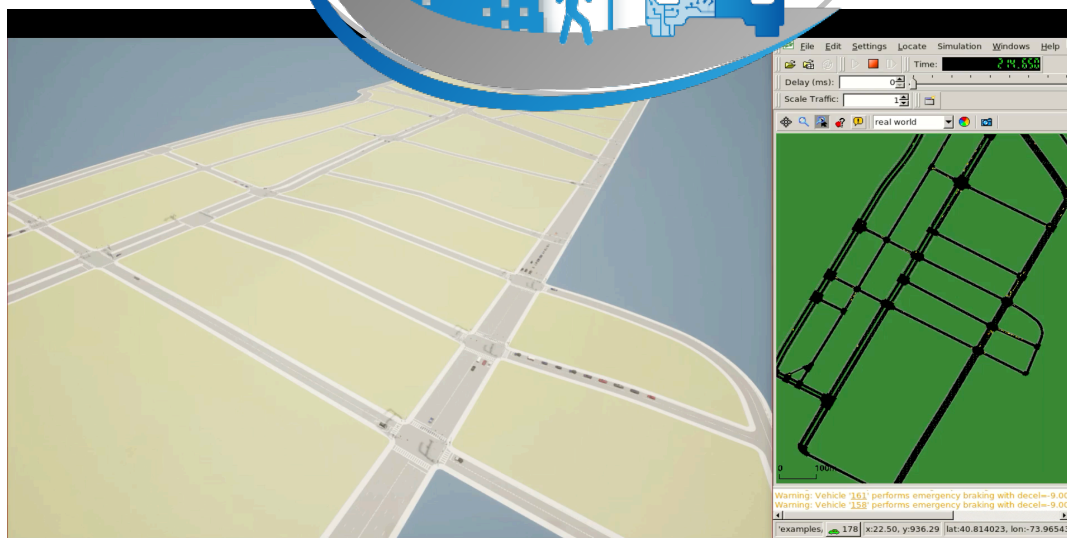


Data



Data Science Challenge

Making Roads Safer for Vulnerable Road Users in Disadvantaged Communities





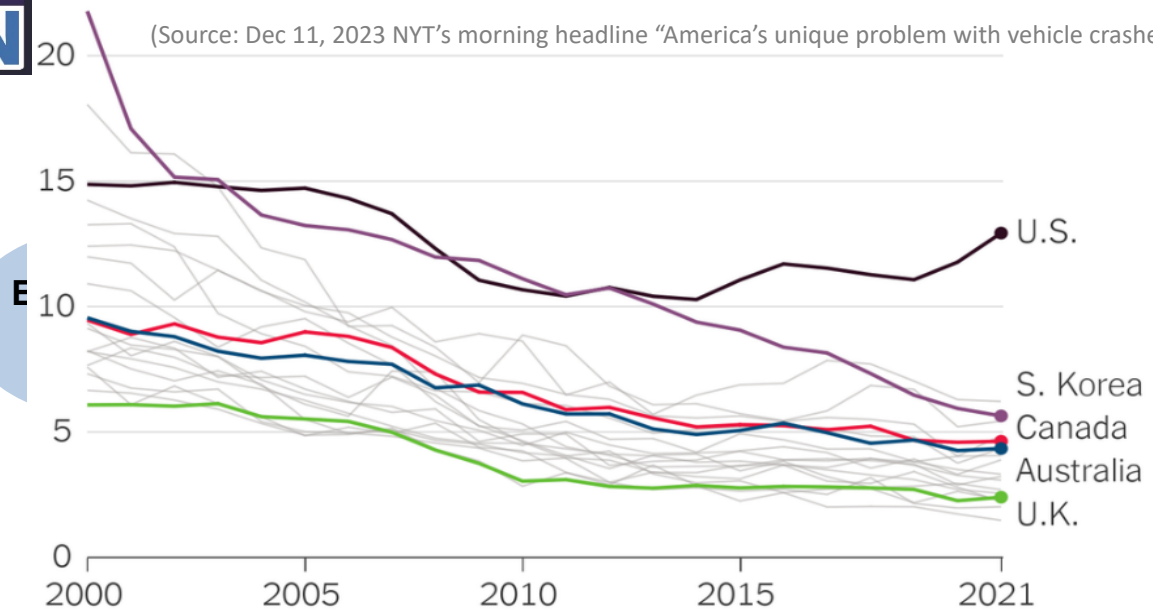
Why now?

Technological Push

- ❖ Ubiquitous sensing
- ❖ Communication
- ❖ Edge cloud computing

Vehicle deaths per 1 million residents, in 20 rich countries

(Source: Dec 11, 2023 NYT's morning headline "America's unique problem with vehicle crashes")



Why useful?

Short-Term

- ❖ *Traffic Operation & Management*
 - Situational awareness
 - Traffic flow smoothing
- ❖ *Planning*
 - Congestion pricing
 - Mobility service system

Long-Term

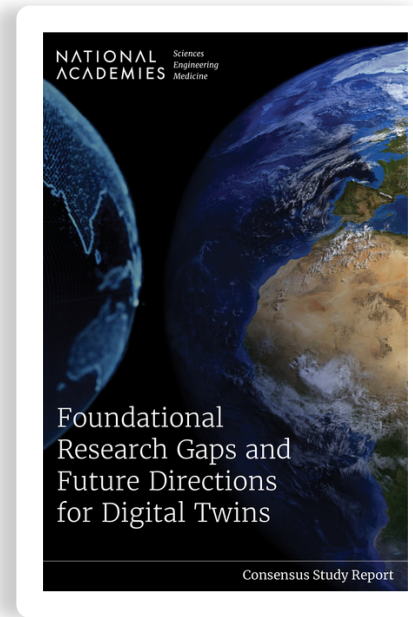
- ❖ *Infrastructure design*
 - Resilience, sustainability
- ❖ *Policymaking & lawmaking*
 - Digital innovation regulation/adaptation

ADD VALUES. CHARACTERIZE, PREDICT, INTERVENE

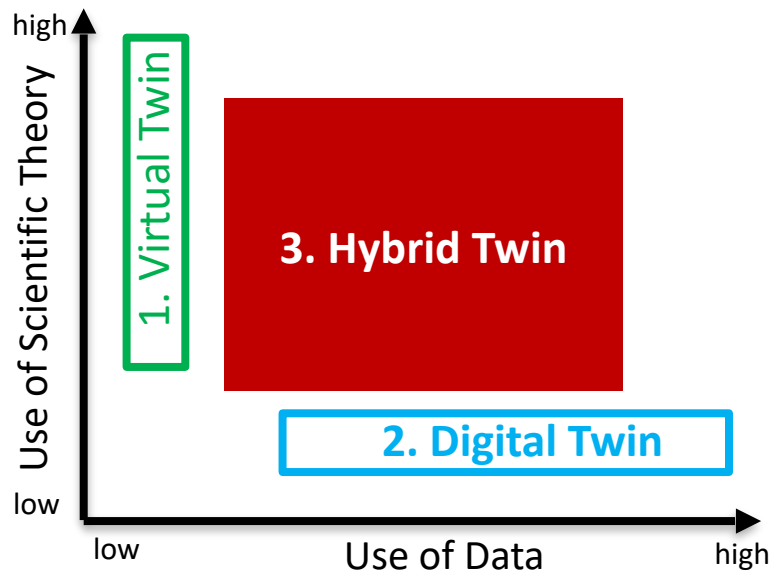
Evolution in Digital Twin

A set of *virtual information constructs* that mimics the structure, context, behavior of a natural, engineered, or social system (or system-of-systems), is *dynamically updated* with data from its *physical twin*, has a predictive capability, and informs decisions that *realize value*.

Physical ↔ Digital



Open-loop: simulators
(Movement of vehicles is simulated using pure physics-based traffic models with a few parameters)



Data & AI-Driven:

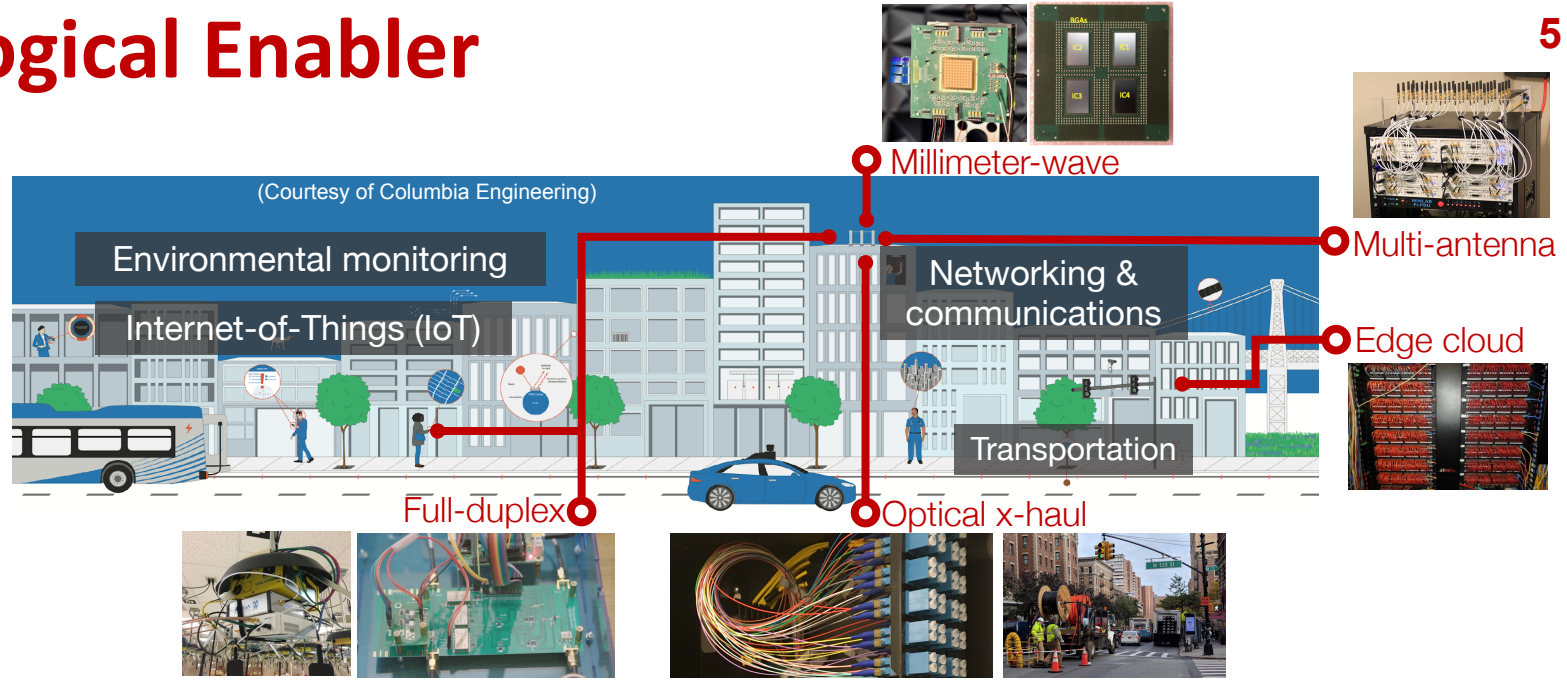
exploit the advantages of both physics-based models & data

Close-loop: data-driven tools for online simulation and optimal control (updated online using continuously fed data and feedback implemented control policies, leveraging ML)

Technological Enabler

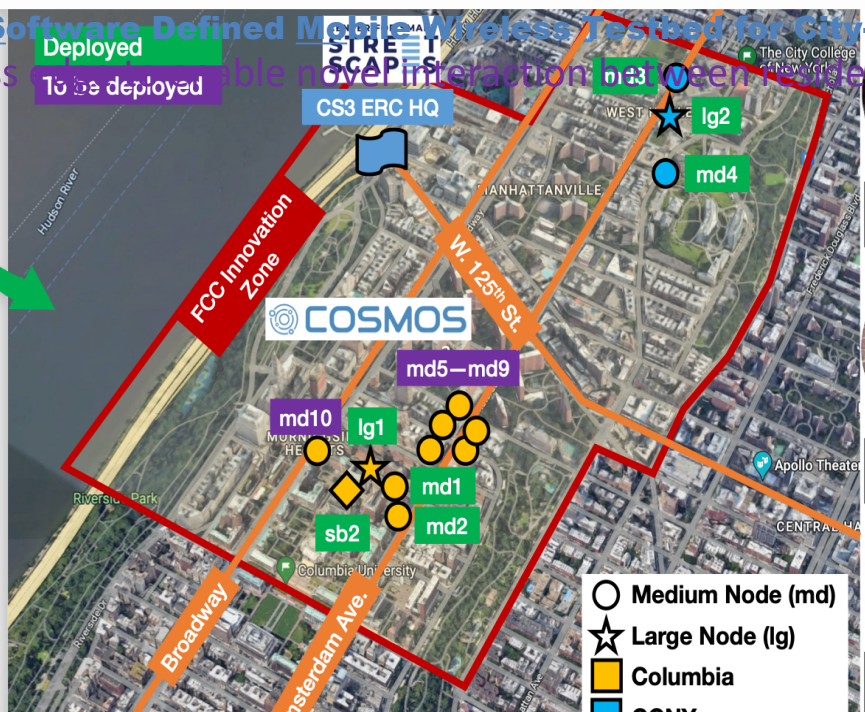
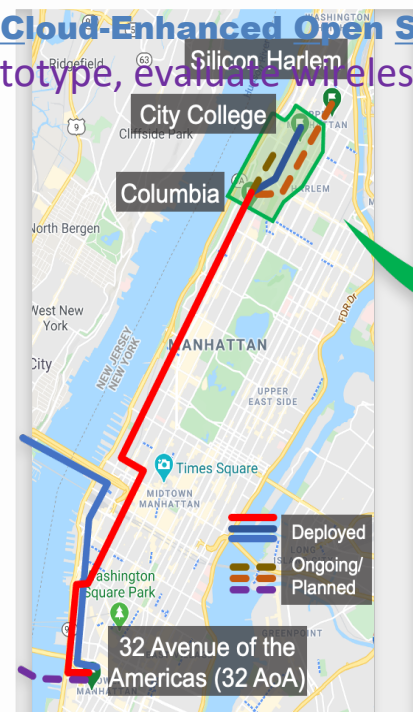


Platforms for Advanced Wireless Research



COSMOS: Cloud-Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment

❖ Design, prototype, evaluate wireless mobile novel interaction, green, agents & urban environ



Large (rooftop)



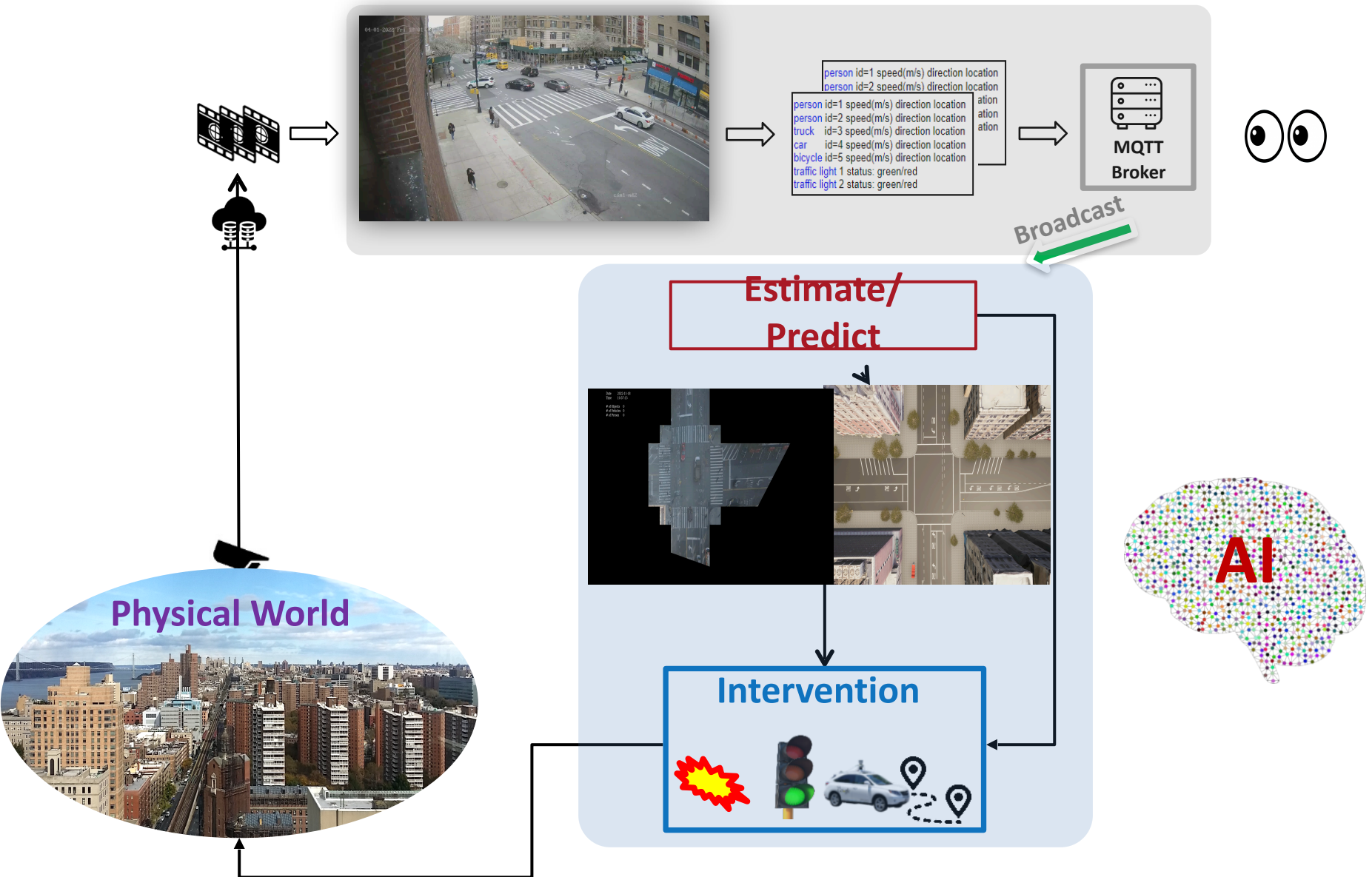
Medium (street-level)



Small (portable)

- Medium Node (md)
- ★ Large Node (lg)
- Columbia
- CCNY

Transport: Spatiotemporal Human-Cyber-Physical System of Systems



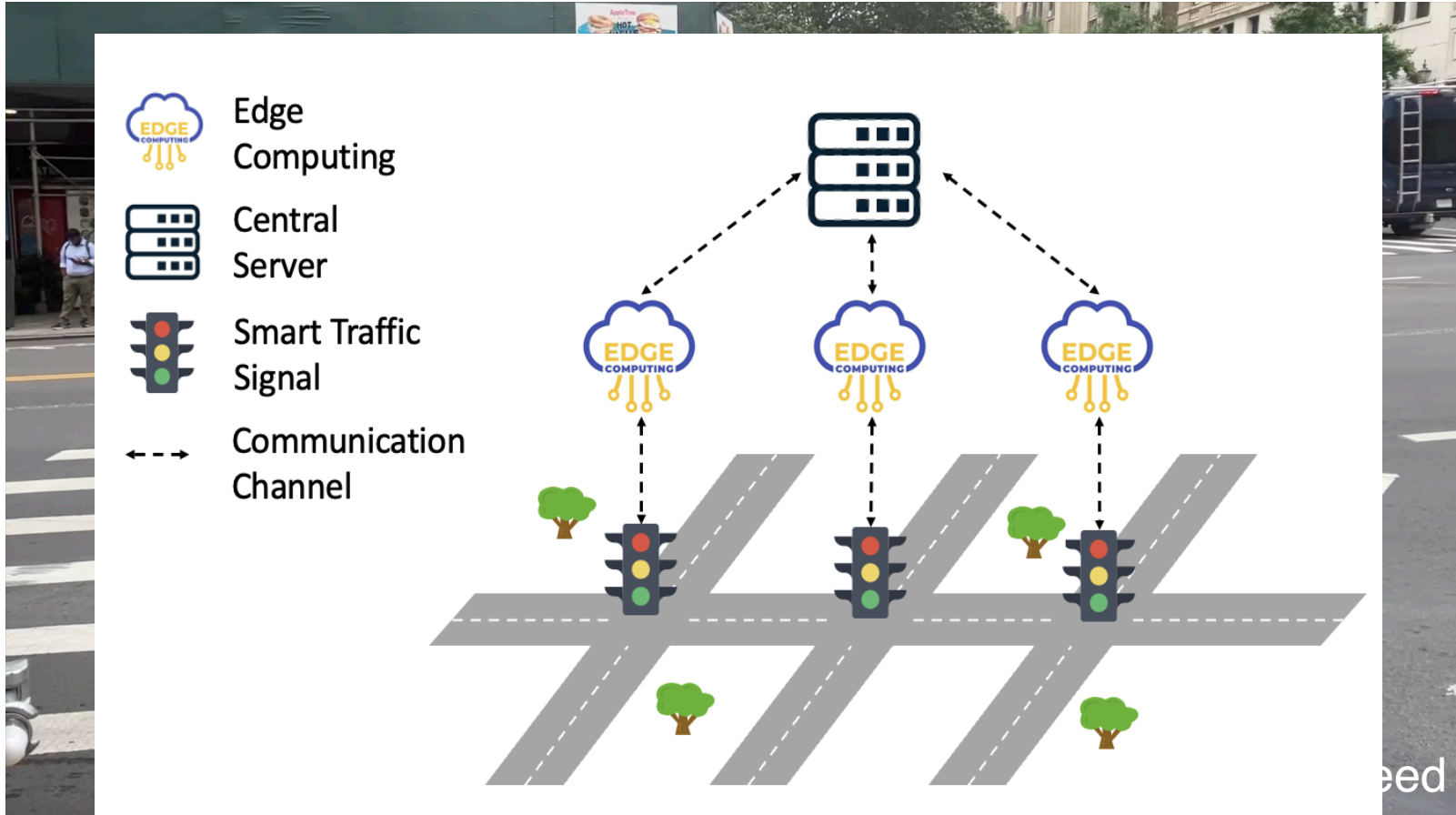
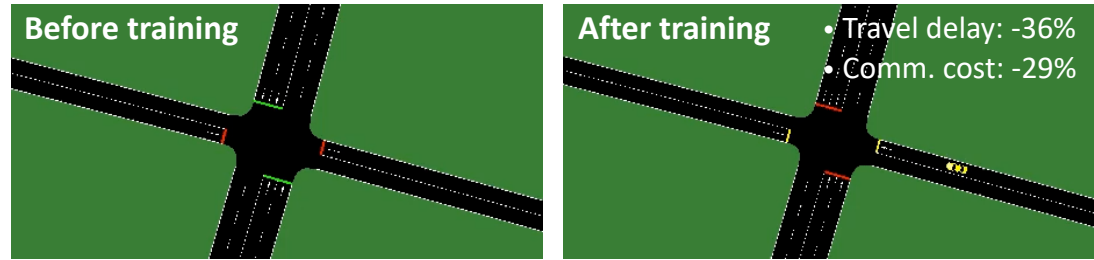
Case Study

Traffic Signal Optimization

Federated Learning

Privacy preservation

Communication cost reduction

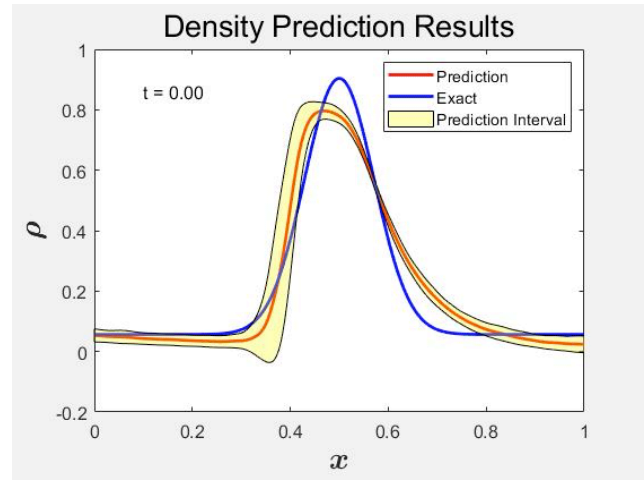
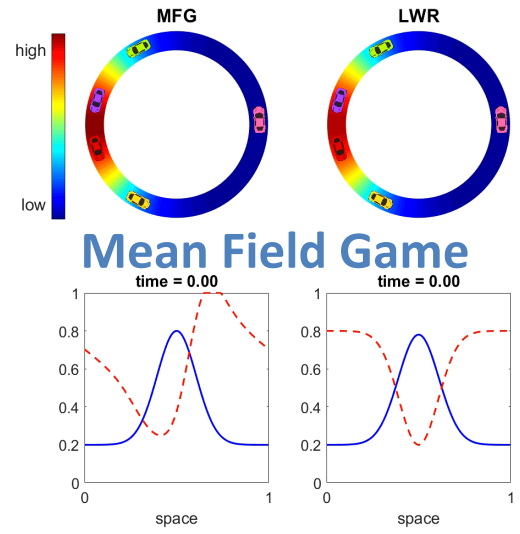
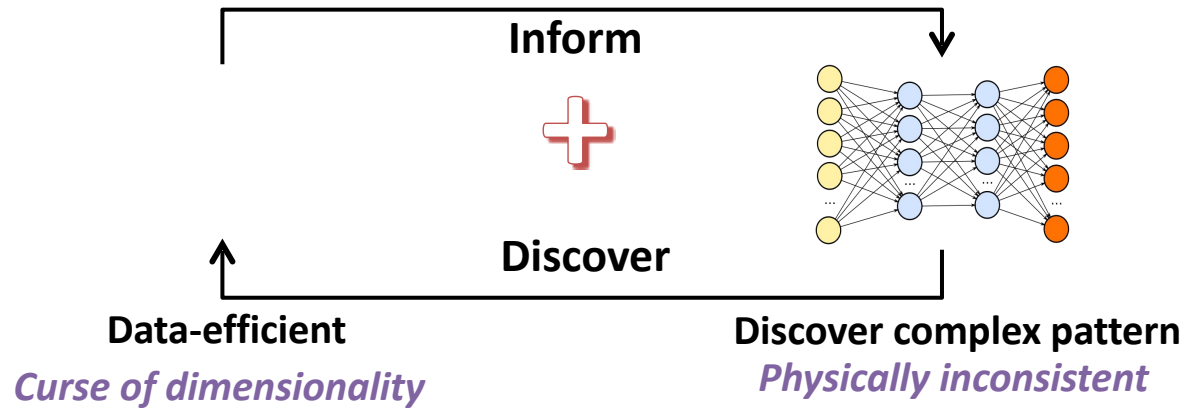


Challenges



- ✓ Multi-scale knowledge discovery
- ✓ Uncertainty quantification
- ✓ Extremes

- ✓ Discontinuity learning
- ✓ Scalable computing



Open Questions

- ✓ **Governance:** Who own and maintain DT, if data are from various entities?
- ✓ **Fidelity:** Multiscale multi-fidelity
- ✓ **Validation/Verification:** Who? How? What?

Acknowledgement

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thank
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