CPS: CAREER: Co-Design of Information and Incentives in Societal-Scale Cyber-Physical Systems

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Motivation: Human decision makers are an integral part of SCPS, yet their behavior is hard to predict since their decision-making processes are dynamic and depend on external inputs.

Aim 1: Algorithms for Learning in SCPS

Objective: development of

(A1.a) foundational models, and

(A1.b) algorithmic approaches for learning them, that capture the decision-making processes of humans in the SCPS loop

Aim 2: Algorithmic Information & Incentive Mechanisms

Objective: design algorithmic mechanisms to

(A2.a) address information asymmetries,

(A2.b) prevent unintended consequences,

(A2.c) ensure fairness & efficiency criteria.

Aim 3: Simulations & Living Labs

Objective: validation & testing via 3-tiered approach:

(Tb.1) high-fidelity simulation environment built on data-informed models,

(Tb.2) interactive lab constructed on top of a simulation platform for assessing policy performance, and

(Tb.3) living labs (UW campus and city of Seattle).

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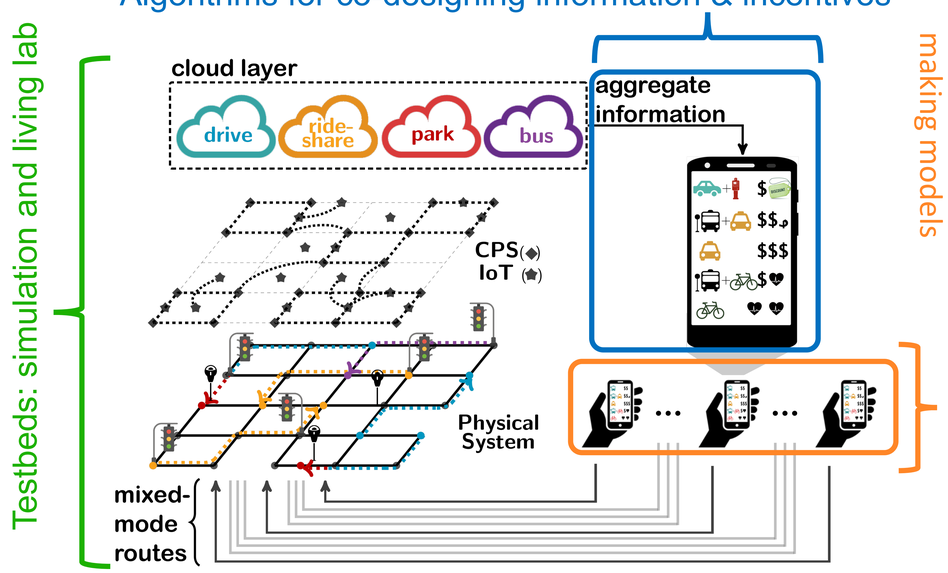
Algorithms for co-designing information & incentives



Selected Outcomes & Products from 2021-- 2022:

- Introduction of a **novel differential approach to bounded rationality** which is amenable to computation [1].
- **Multiplayer Performative Prediction**: Learning in decision-dependent games wherein each player has a data distribution (capturing strategic agents in the environment) that depends on the joint action [2],
- **Learning in the presence of strategic agents**: robustness to strategic user model misspecification via distributionally robust optimization [4], and efficient algorithms for learning given a dynamic decision-dependent data distribution [5].
- **Provable convergence of gradient-based learning** in zero sum games [6-8] and strongly monotone [3]
- **Efficient and adaptive data collection**: using active learning and experiment design techniques we developed and tested algorithms for collecting ground truth parking data given budget constraints [9]

Scientific Impact:

- This project aims to lay the theoretical and algorithmic foundations for the design of both information and incentive mechanisms in S-CPS
- Provides robust mechanisms to AI-enabled CPS at scale

Broader Impact:

- SDOT (via Turnstone) has now adopted a data-informed model-based (e.g.,[12]) for occupancy which it uses to set parking policy including prices as opposed to basing decisions based on single-day samples once per year.
- Developed undergraduate course (Spring '22) on foundations of machine learning and optimization that highlights applications in SCPS
- REU:
  - –undergrads working on platform for experimentally validating differential bounded rationality models via "games"
  - –Aiding in the policy simulator development

[1] Chasnov, Ratliff, Burden. submitted to Science, 2022
[2] Narang, Faulkner, Drusvyatskiy, Fazel, Ratliff. AISTAT
[3] Drusvyatskiy, Ratliff, IEEE CDC 2022. arXiv: 2111.09456
S, 2022; arXiv: 2201.03398
[4] Maheshwari, Chiu, Mazumdar, Sastry, Ratliff. AISTATS, 2022
[5] Ray, Drusvyatskiy, Fazel, Ratliff. AAAI 2022; arXiv: 2204.08281
[6] Fiez, Ratliff, Mazumdar, Narang, Faulkner NeurIPS, 2021
[7] Fiez, Ratliff. ICLR 2021; arXiv: 2009.14820
[8] Fiez, Chasnov, Ratliff, ICML 2021; arXiv: 1906.01217
[9] Faulkner, Ratliff. Under review, 2022