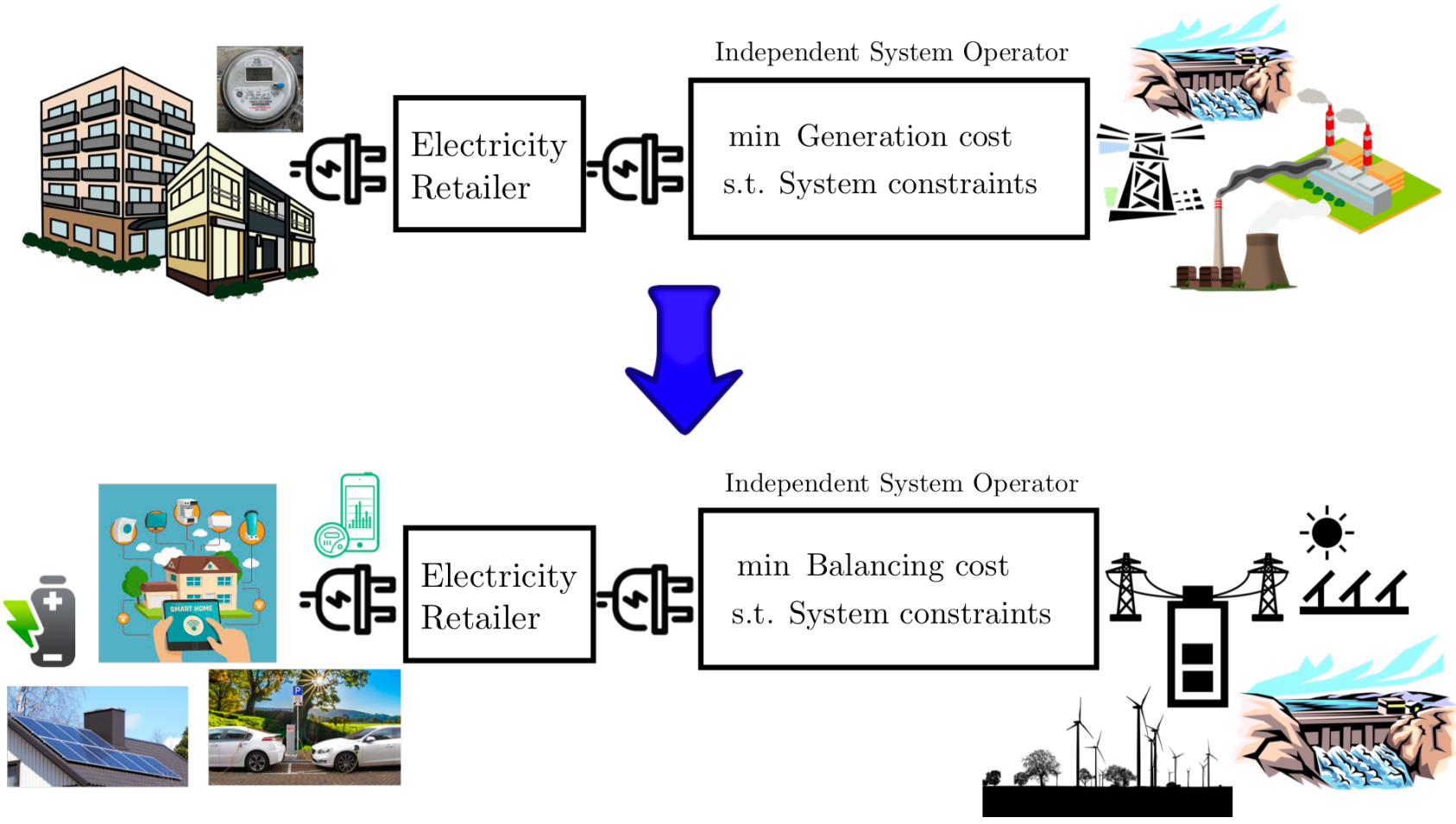
Learning to optimize electricity demand

Mahnoosh Alizadeh
UC Santa Barbara

June 2021
CPS PI meeting CAREER Panel

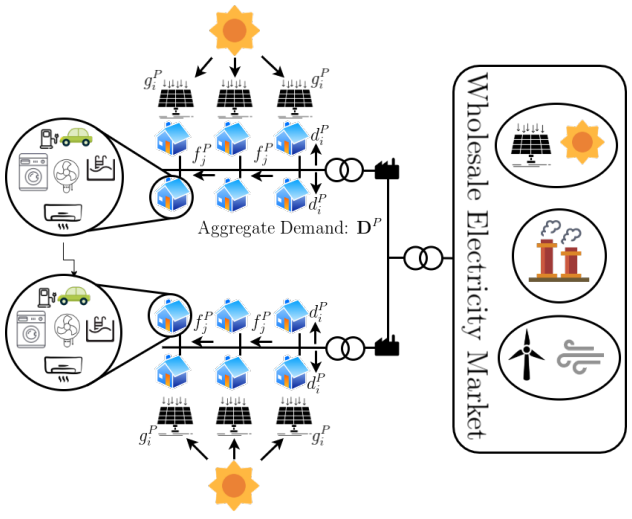
A customer-centric energy transformation



Basic principles: Grid-scale and distributed renewable energy production, increased customer engagement, transportation electrification, storage

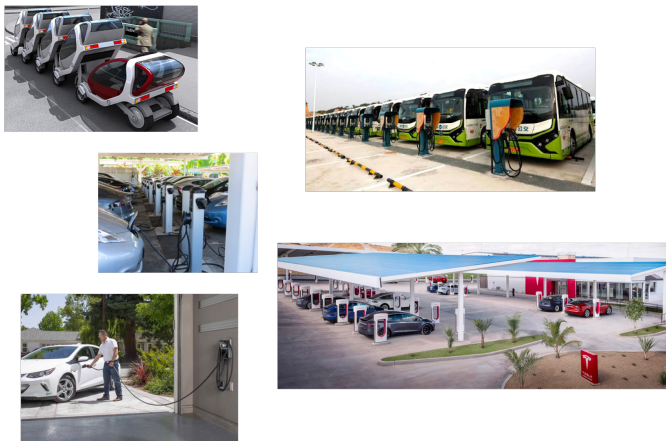
Twin goals of CAREER proposal

New theory for data-driven demand response with reliability guarantees



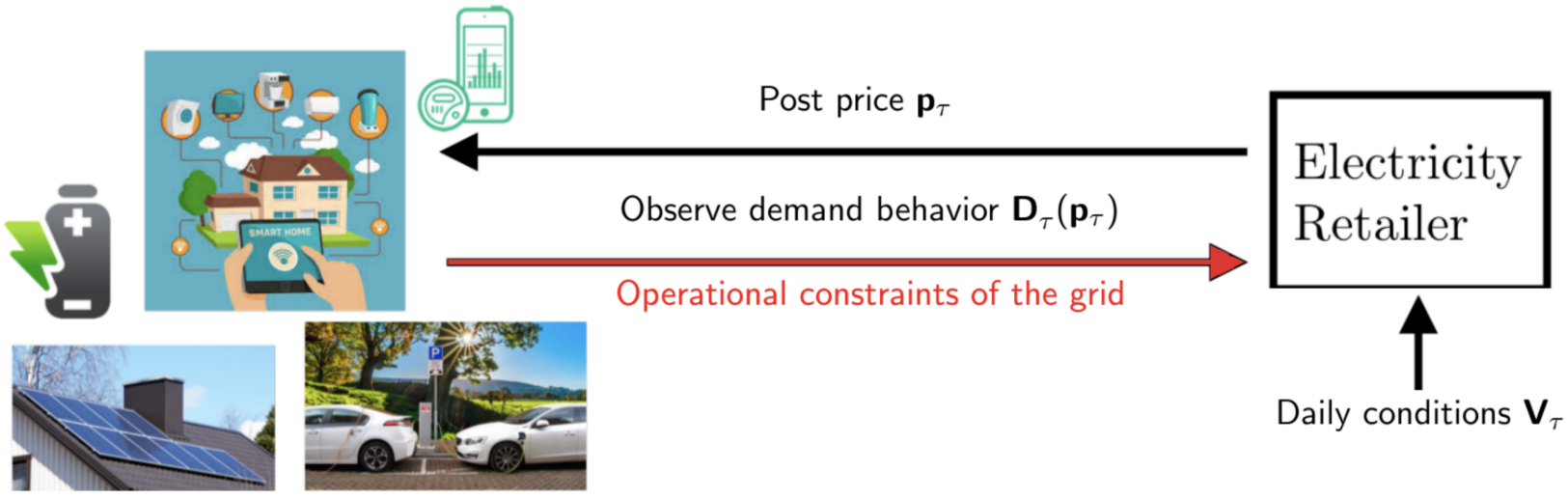
Challenges:
Strict relieability reqs, Unrelieable models, High uncertainty, Cyber-security

Specific application area:
Real-time mobility-aware electric vehicle smart charging



First, I will highlight two theoretical thrusts with broader CPS applications

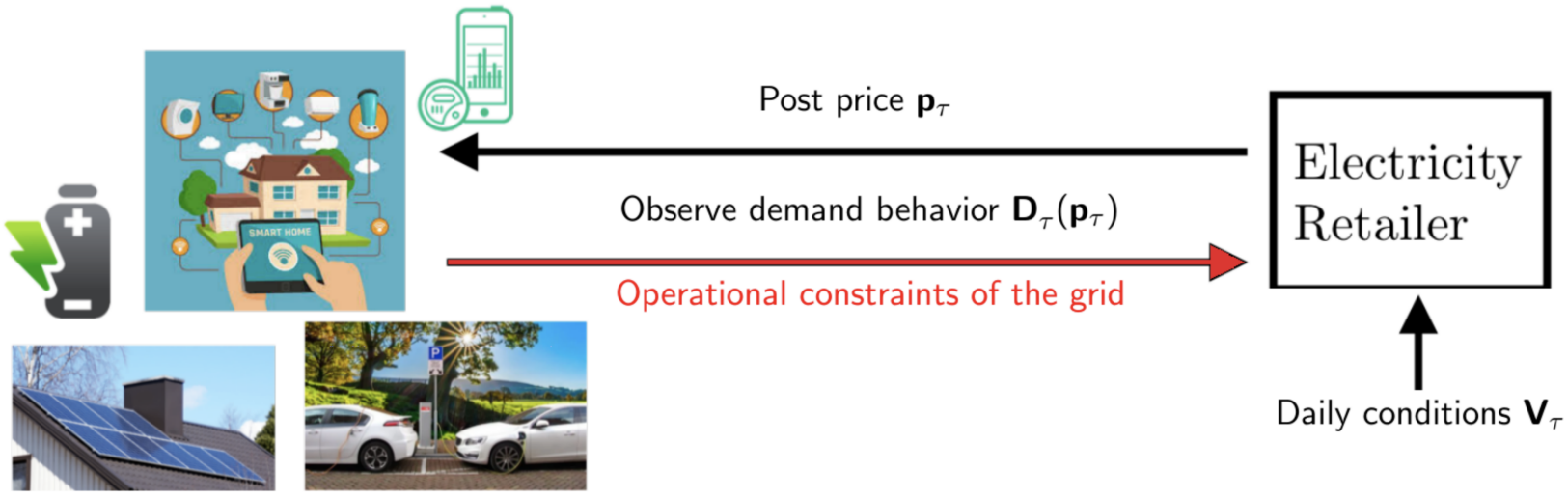
1st highlight: Data-driven optimization for DR



Objective: minimize expected cost $\mathbb{E}\left[f\left(\mathbf{D}_\tau(\mathbf{p}_\tau), \mathbf{V}_\tau\right)\right]$
Subject to: operational constraints of the grid

- Challenge: Learn demand flexibility from repeated interactions

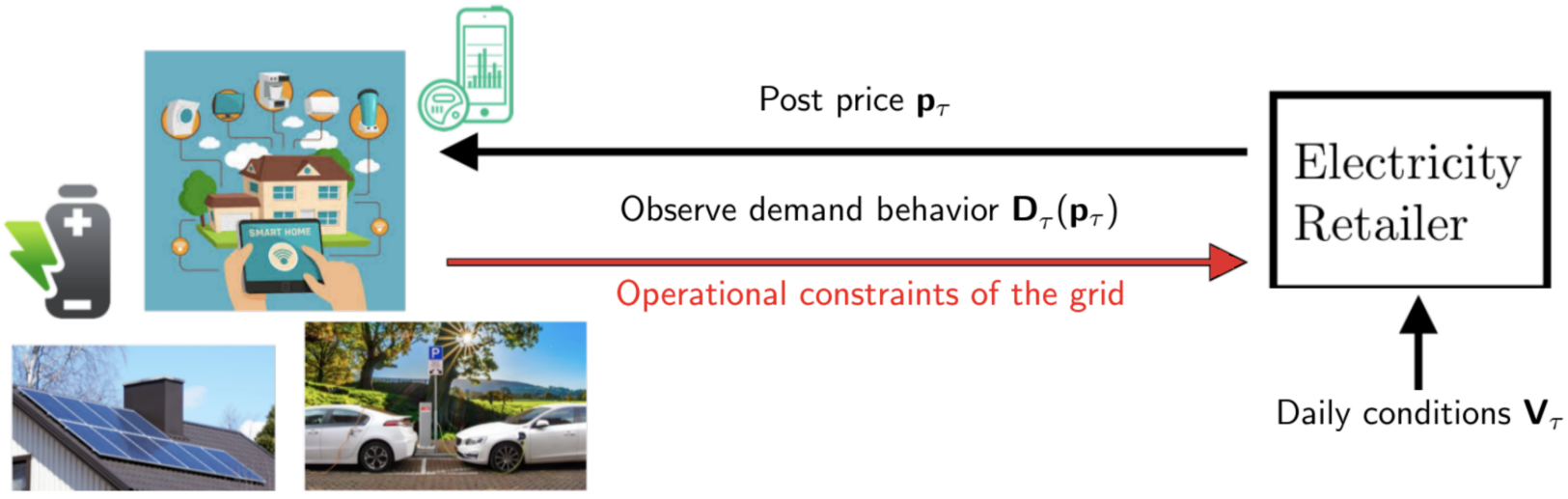
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- Retailer's goal: Minimize $\sum_{t=1}^{365}$ daily costs

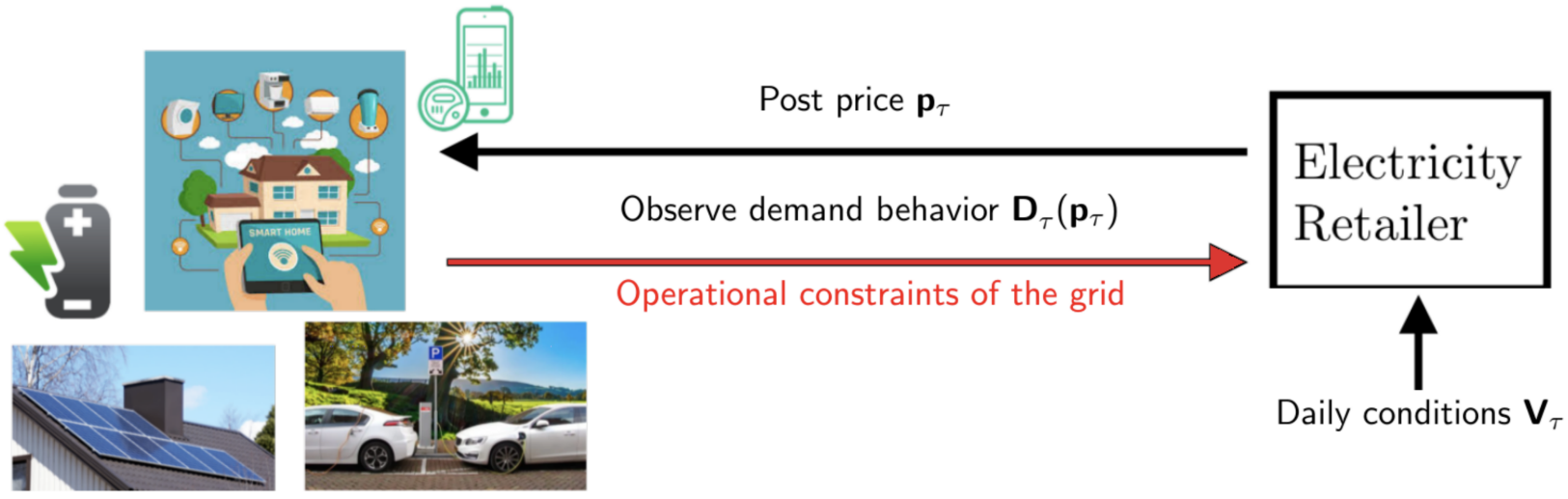
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- Constraint: Don't blow up the grid! $\rightarrow$ Dist flow constraints

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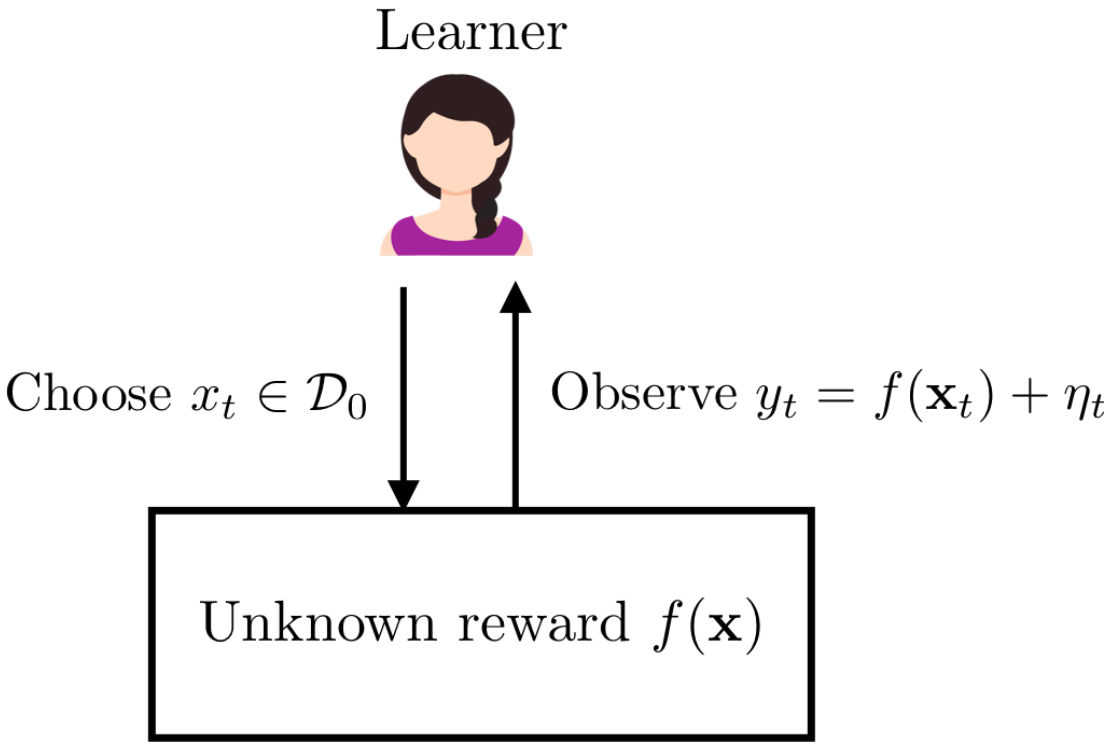
Objective: minimize expected cost $\mathbb{E}\left[f\left(\mathbf{D}_\tau(\mathbf{p}_\tau), \mathbf{V}_\tau\right)\right]$
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- Constraint: Don't blow up the grid! $\rightarrow$ Dist flow constraints

What type of mathematical tool can address such a problem?

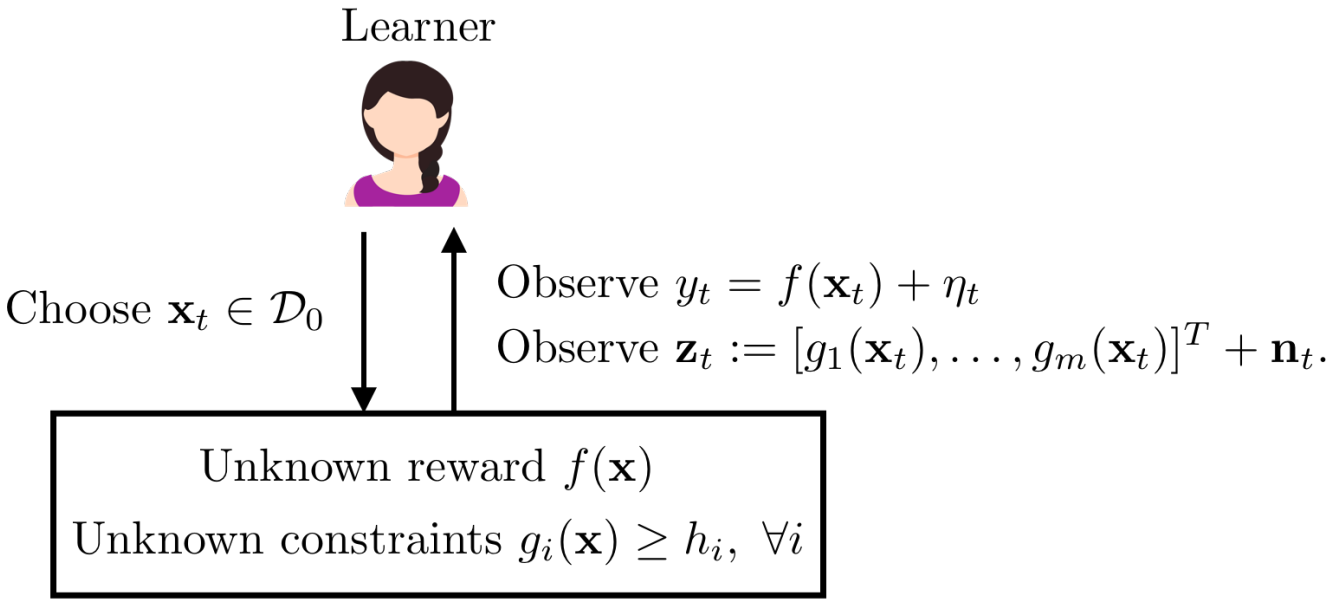
Stochastic bandit optimization

System with unknown reward function $f \rightarrow$ Learner wants to maximize total expected reward from a finite number of interactions



Safety-constrained bandits with application to DR

Safety-critical systems have constraints that need to hold at every round!



Goal:
1) minimize $R_T = \sum_{t=1}^{T} f(\mathbf{x}^*) - f(\mathbf{x}_t)$
2) Respect constraints at all rounds $t = 1, \ldots, T$

Highlighted publications: [TSG '20], [NeurIPS '19], [NeurIPS '20]

2nd highlight: Algorithmically-robust distributed DR

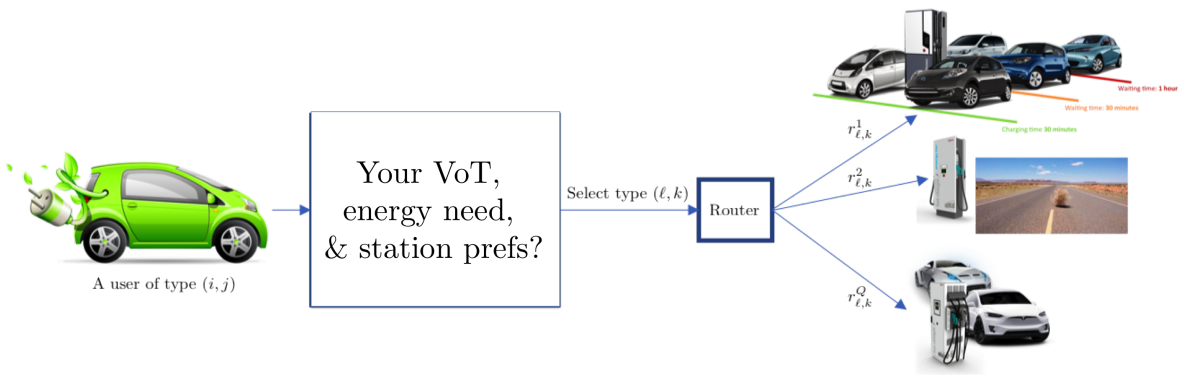
Many solutions for demand response rely on distributed optimization



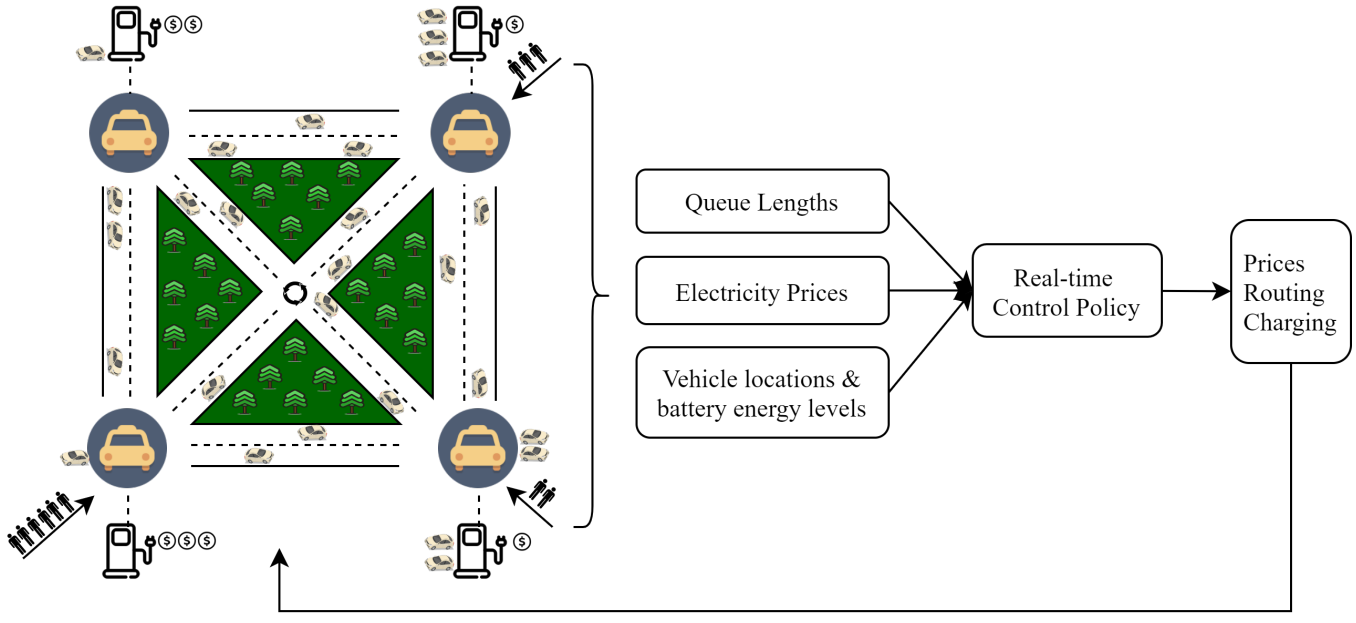
Highlighted publications: [TCNS '20],[ACC '21]

Mobility-aware electric vehicle routing and charging

[TSG '20]: Differentiated service menus for EV public charging

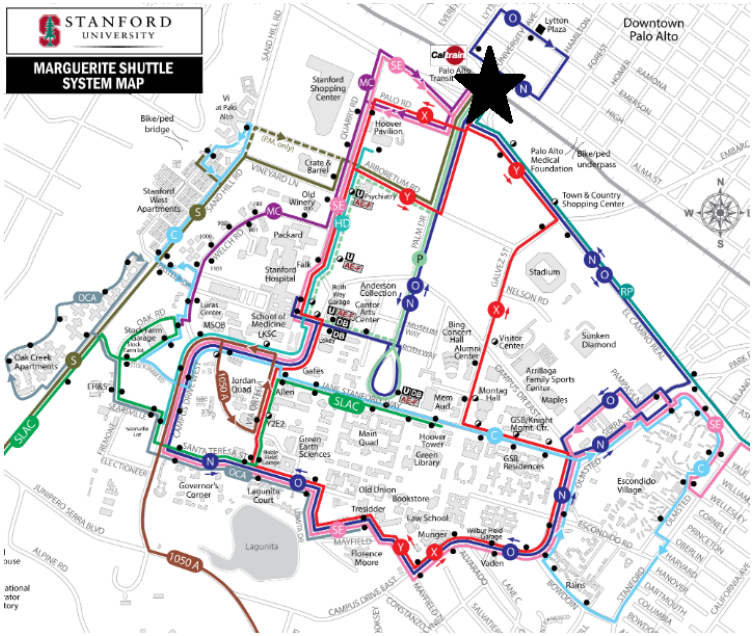


[TCNS '20], [TRC '20]: Real-time management of AMoD EV fleets



Real-world implementations through industry collaborations

Collaboration with SLAC national lab and Chargepoint allows us to test our algorithms (funded by separate CEC projects):



Stanford University Shuttle System



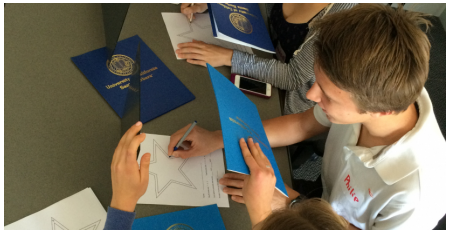
Google Mountain View Campus

Educational and outreach efforts

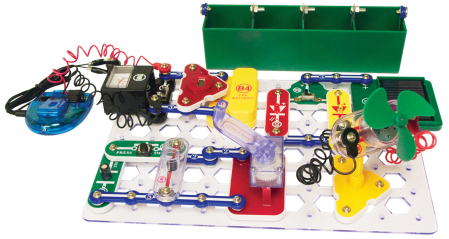
EUREKA program: underrepresented undergraduate students



"Power and Energy Saturday Academy" for high school students



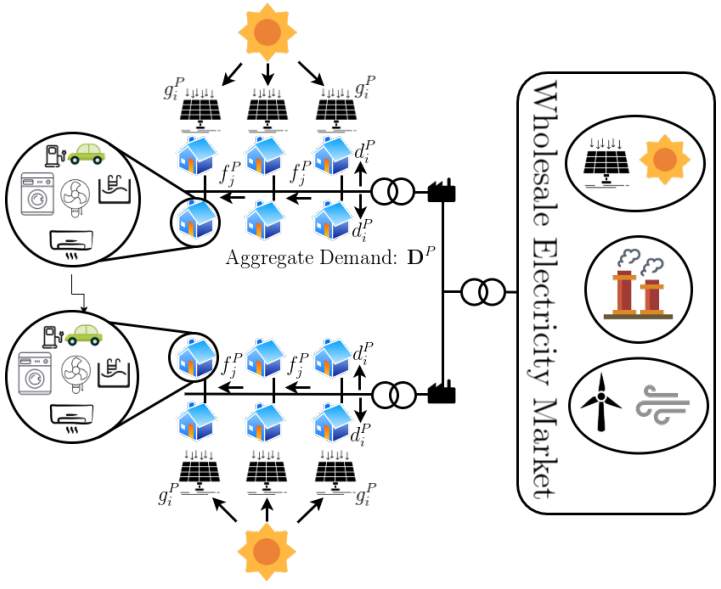
"Kids in Energy" elementary school class for kids and parents



Plus new undergrad and grad classes on smart grid and electric vehicles

Thank you for listening!

Please don't hesitate to reach out for any questions



Thanks to generous support from the National Science Foundation under Grants 1847096 (CAREER), 1837125 (CPS).