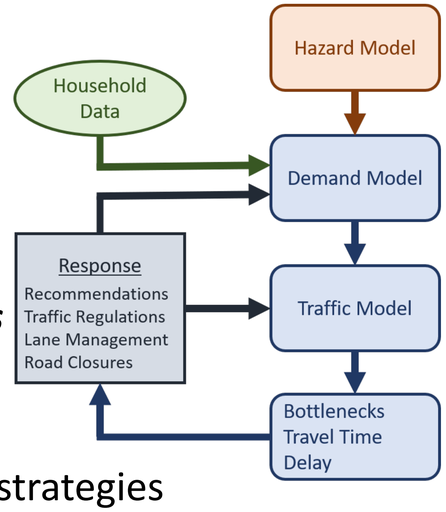
Collaborative Research: CPS: Medium: Population Games for Cyber-Physical Systems: New Theory with Tools for Transportation Management under Extreme Demand

Murat Arcak and Alex Kurzhanskiy (UC Berkeley), Nuno Martins (University of Maryland)

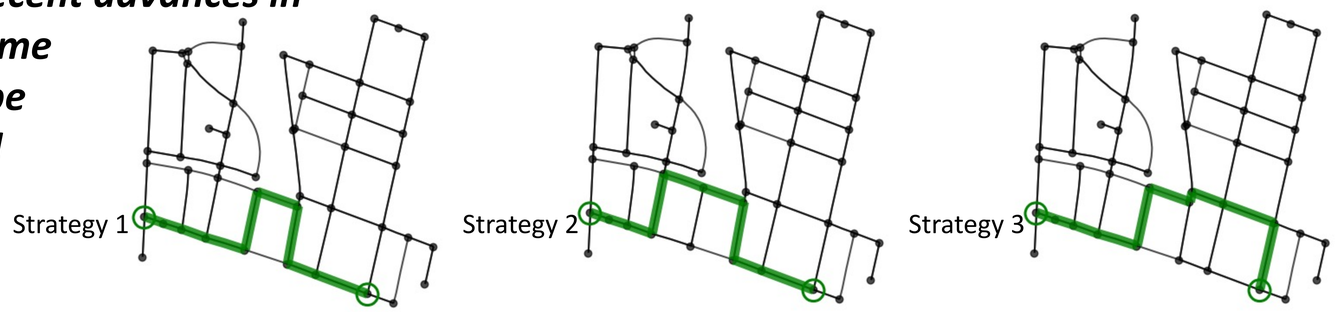
Challenge:

- Accounting for users' ***strategic behavior in CPS***
- ***Coupling of strategic behavior with CPS dynamics*** determines transients and outcomes in ***evacuations, epidemics, etc.***
- Mechanism design to ***shape transients and outcomes***



Approach:

- ***Population Games***: keep track of ***frequency of each strategy*** in a population rather than individual agent strategies
- Key to ***scalability to large numbers of agents***
- ***Learning rules for switching strategies*** lead to classes of ***evolutionary dynamics*** models
- This project: 1) ***accounts for coupling of evolutionary and CPS-dynamics***; 2) ***leverages recent advances in population game theory to shape transients and outcomes***



Scientific Impact:

- ***Contributions to the core theory of population games and evolutionary dynamics***; e.g., generalizations to infinite strategy sets [ASA23] and differential equation modeling of evolutionary dynamics [KMA22, KM23, KM24]
- ***Applications in transportation***; e.g., optimal EV charging station placement to mitigate congestion [SKKA23]
- Demonstrated broad applicability beyond transportation; e.g., ***epidemic response*** – managing public's strategic choices with incentives [CML22, MCL23, CLM23]

Education and Outreach:

- ***Full-day workshop at the 2023 IEEE Conference on Decision and Control***: https://sites.google.com/view/cdc2023population-games
  - One-unit ***graduate course*** at UC Berkeley in Spring 2023
  - ***Seminars*** at UIUC, Berkeley, Maryland
    - ***Presentation to California Department of Transportation***

Publications:

[ASA23] Anderson, Sojoudi, Arcak. ***Evolutionary games on infinite strategy sets: convergence to Nash equilibria via dissipativity.*** (arXiv.2312.08286)

[CML22] Certório, Martins, La. ***Epidemic population games with nonnegligible disease death rate.*** IEEE Control Systems Letters, vol. 6, pp. 3229-3234, 2022. (DOI: 10.1109/LCSYS.2022.3183477)

[CLM23] Certório, La, Martins. ***Epidemic population games for policy Design: two populations with viral reservoir case study***. 2023 IEEE CDC. (DOI:10.1109/CDC49753.2023.10383665)

[KMA22] Kara, Martins, Arcak. ***Population games with Erlang clocks: Convergence to Nash Equilibria for Pairwise Comparison Dynamics***. 2022 IEEE CDC. (DOI: 10.1109/CDC51059.2022.9993228)

[KM23] Kara, Martins***. Differential equation approximations for population games using elementary probability***. (arXiv. 2312.07598)

[KM24] Kara, Martins***. Learning Nash Equilibria in Large Populations with Networked Strategies***. (Under review)

[MCL23] Martins, Certório, La. ***Epidemic population games and evolutionary dynamics***. Automatica, vol. 153, 2023. (DOI: 10.1016/j.automatica.2023.111016)

[SKKA23] Sonmez, Kizilkale, Kurzhanskiy, Arcak. ***Optimal electric vehicle charger placement as a congestion game problem***. (Under review)

Berkeley UNIVERSITY OF CALIFORNIA · UNIVERSITY OF MARYLAND · NSF CNS-2135561 & 2135791