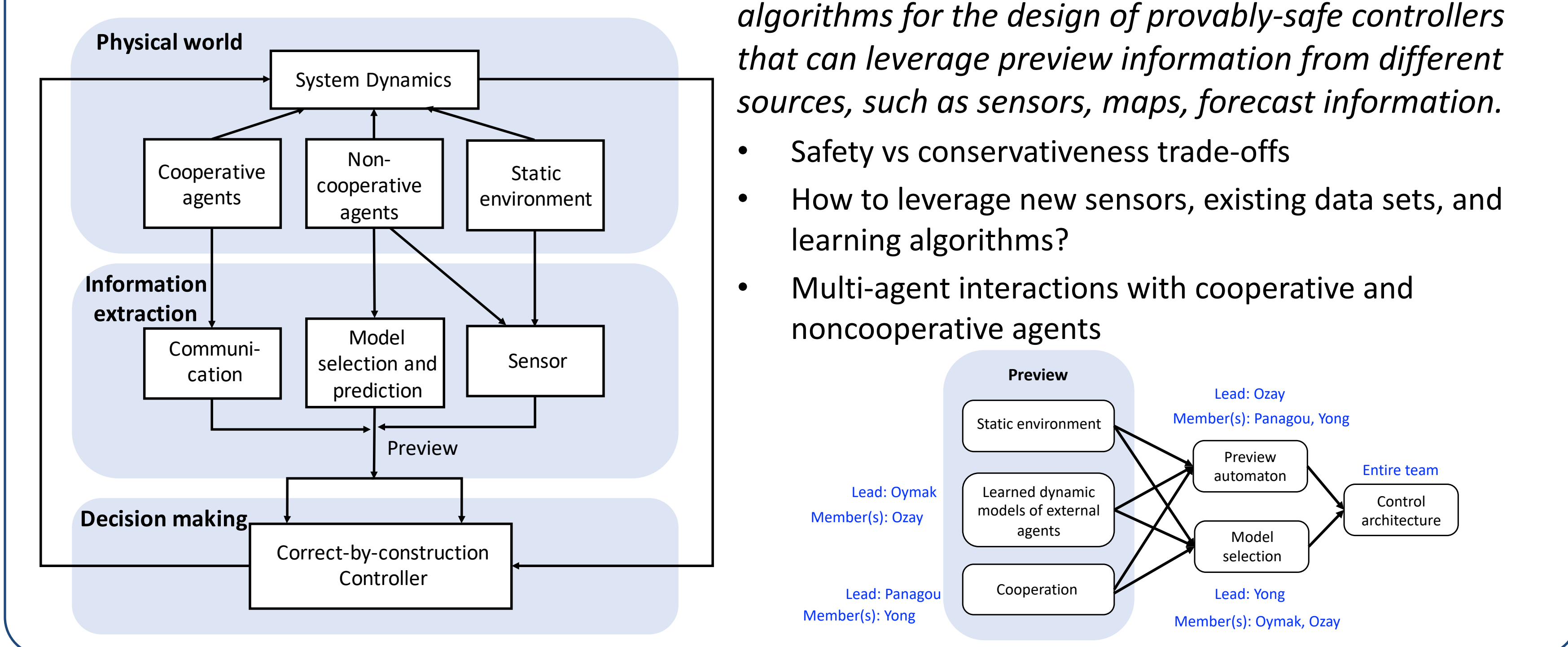


CPS: Medium: Collaborative Research: Data-Driven Modeling and Preview-Based Control for Cyber-Physical System Safety

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Motivation



Scientific Impacts

- Understand the role of multi-agent cooperation in providing preview information via data-driven models and communication
- Enable the incorporation of preview information using preview automata
- Develop theory and algorithms for guaranteeing safety with preview information with model selection and state estimation

Broader Impacts

- ### Impact to Society
- Application focus: Driver assist systems
- Improving driving safety can save lives
- Broadly applicable methodology
- Can generalize to a wide class of CPS, e.g., UAVs, robots, medical devices
- ### Education and Outreach
- Graduate student researchers: Mitchell Black, Mohammad Khajenejad, Zexiang Liu, Yahya Sattar
 - Broadening participation in computing and engineering plan targets female undergrads at UM (and Midwest) and minority undergrads at UCR and ASU to prepare and encourage them to pursue graduate studies in STEM.

Selected Publications

[1] Z. Du et al. "Data-driven control of Markov jump systems: Sample complexity and regret bounds", ACC'22.

[2] Y. Sattar, S. Oymak and N. Ozay, "Finite sample identification of bilinear dynamical systems", CDC '22.

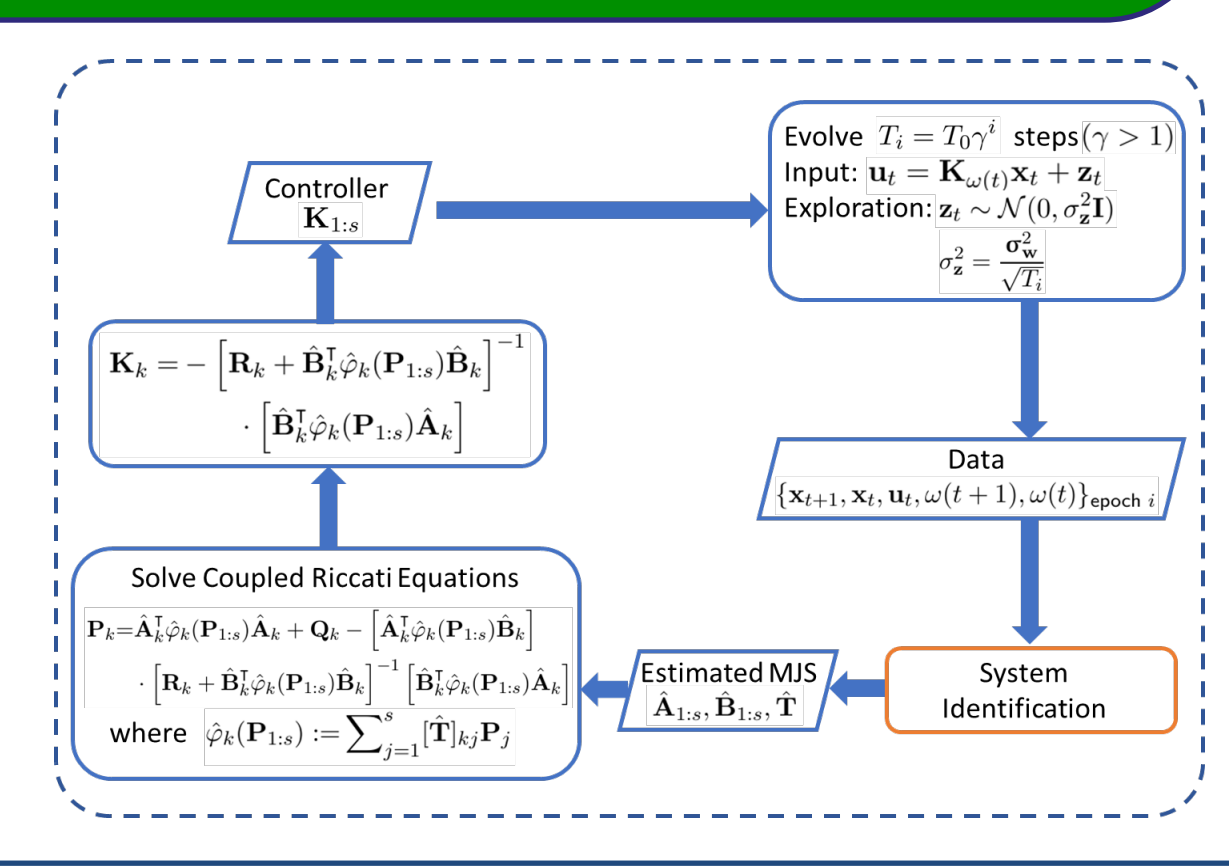
[3] M. Black, and D. Panagou. "Adaptation for Validation of a Consolidated Control Barrier Function based Control Synthesis". Submitted to ICRA'23.

[4] Liu, Z., & Ozay, N. "On the Convergence of the Backward Reachable Sets of Robust Controlled Invariant Sets For Discrete-time Linear Systems" CDC'22.

[5] Khajenejad, M., Shoaib, F. and Yong, S.Z., Guaranteed State Estimation via Direct Polytopic Set Computation for Nonlinear Discrete-Time Systems. IEEE LCSS'21.

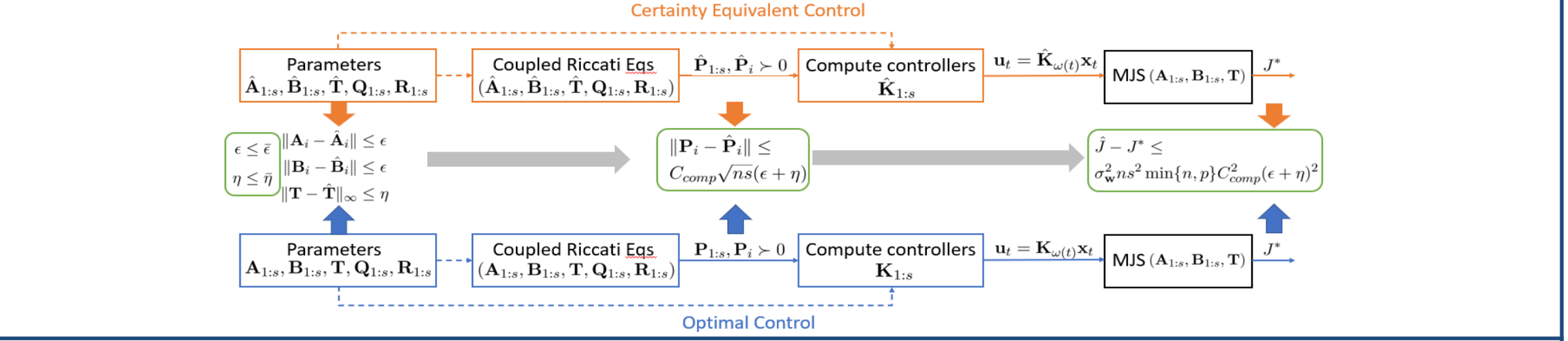
[6] Khajenejad, M., Shoaib, F. & Yong, S.Z. "Interval Observer Synthesis for Locally Lipschitz Nonlinear Dynamical Systems via Mixed-Monotone Decompositions." ACC'22.

Methods and Results



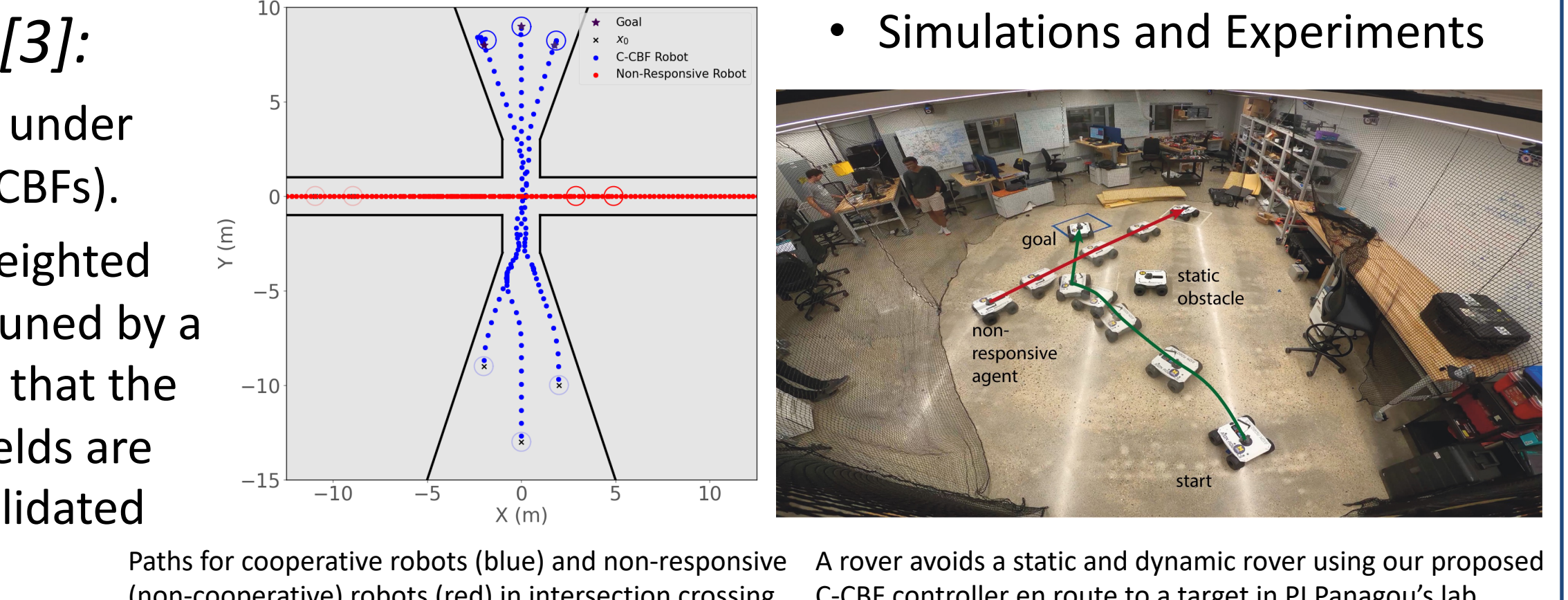
Learning dynamic policy models of external agents [1,2]:

- Derive finite sample complexity and statistical error bounds for learning Markov jump linear systems (MJLS) and bilinear systems.
 $T \gtrsim \mathcal{O}(d)$ and $\|\hat{\theta} - \theta^*\| \lesssim \mathcal{O}(\sigma\sqrt{d}/\sqrt{T})$
- Develop an adaptive control scheme for MJLS: $Regret \lesssim \mathcal{O}(\sqrt{T})$



Certifiable Consolidated CBFs [3]:

- Adaptation-based safety validation under multiple control barrier functions (CBFs).
- A consolidated CBF is defined by weighted multiple CBFs, whose weights are tuned by a novel parameter adaptation law so that the coefficients of the control vector fields are non-vanishing, certifying the consolidated CBF as valid for safety assurance.



Impact of preview on safety control ([4] and ongoing work):

- Provide inner/outer approximations of the maximal controlled invariant set for systems with preview;
- Prove that the size of projected maximal controlled set for linear systems converges exponentially fast with the preview time;
- Develop algorithms to quantify the value of preview for safety control;
- Demonstrate the proposed method via numerical examples in biped robots, autonomous vehicles and power systems.

Run-time set-valued estimation [5, 6]:

