Scalable and Customizable Intent Inference and Motion Planning for Socially-Adept Autonomous Vehicles

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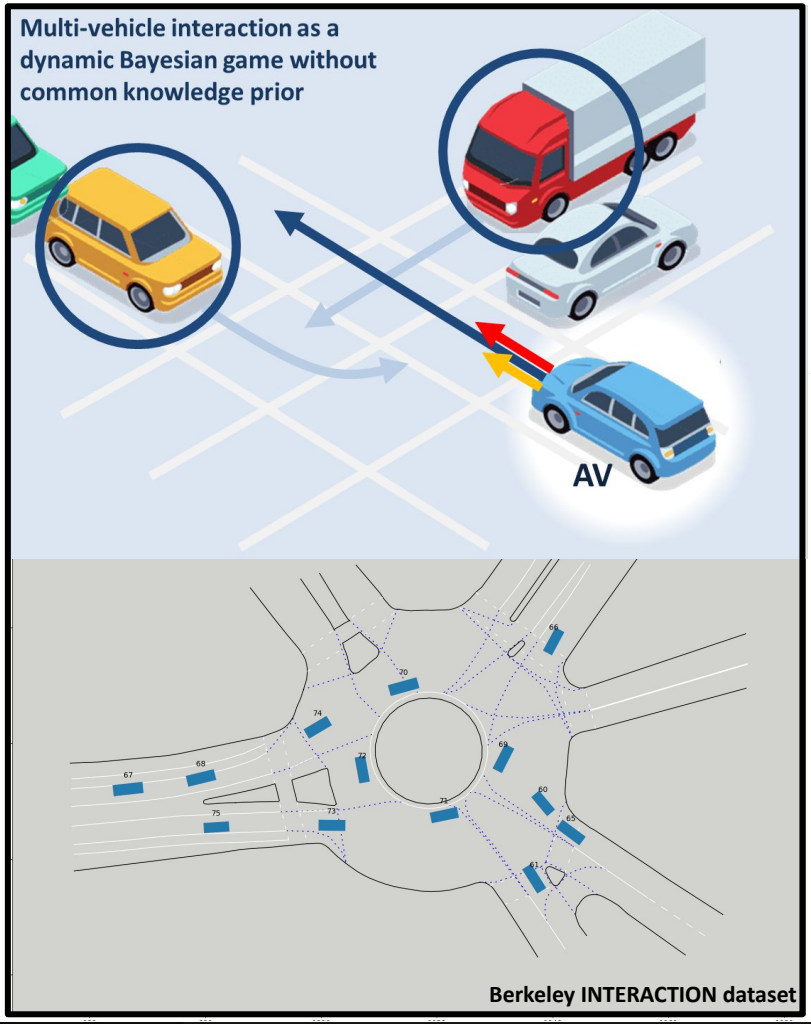
Challenge

- Interactions are differential games w/ *incomplete-information*
- Computing perfect Bayesian equilibrium (PBE) at scale and in real time is an *open question*
- Intent inference and motion planning rely on PBE

Solution

- Real-time equilibrium searching via learning of motion and belief dynamics through traffic data and game theory
- Scalable computation via reduction of interaction graph based on value sensitivities



Scientific Impact

- Enable accurate intent inference and effective signaling during multi-agent interactions
- Enable safe and robust interaction via long-term adaptation of social value orientation, common belief, and solution concepts

Broader Impact

- Collaboration with Institute of Automated Mobility/Intel (ongoing)
- 2 REU interns on conf. papers and honor thesis (ongoing)
- Interdisciplinary course on human-robot interaction (in plan)

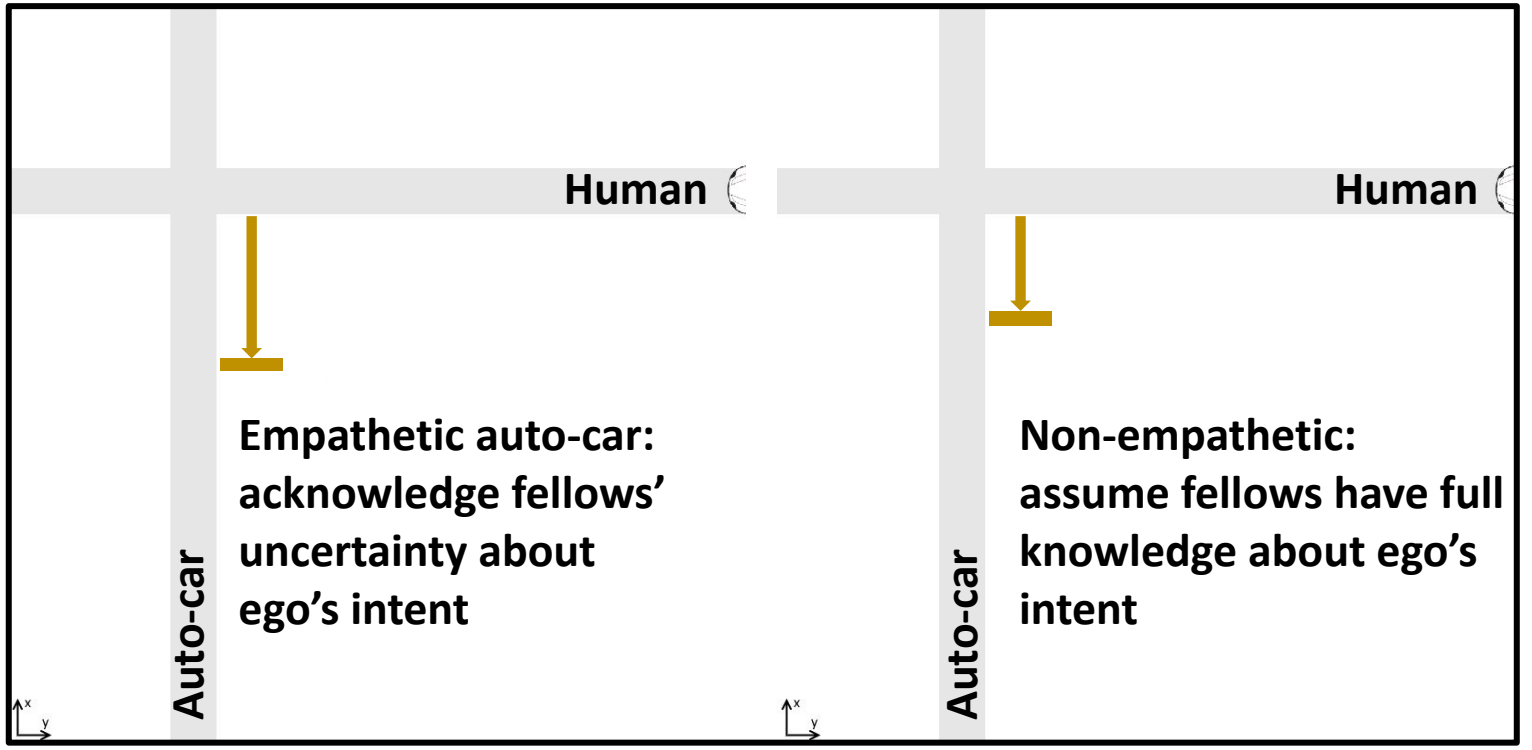
Ongoing work 1: Intent inference & motion planning via equilibrium approximation for incomplete-information games

Contributions to Intent Inference

- Inference via bounded rationality, Bayesian belief update & *equilibrial Hamiltonian approximation* [1]
- Hamiltonian incorporates belief uncertainty, approximated via *learning of co-state dynamics* [1]

Contributions to Interaction

- *Empathy* improves inference accuracy, especially when agents have biased prior beliefs [1]
- *Rational courtesy* is enabled via empathetic intent inference [2,3]

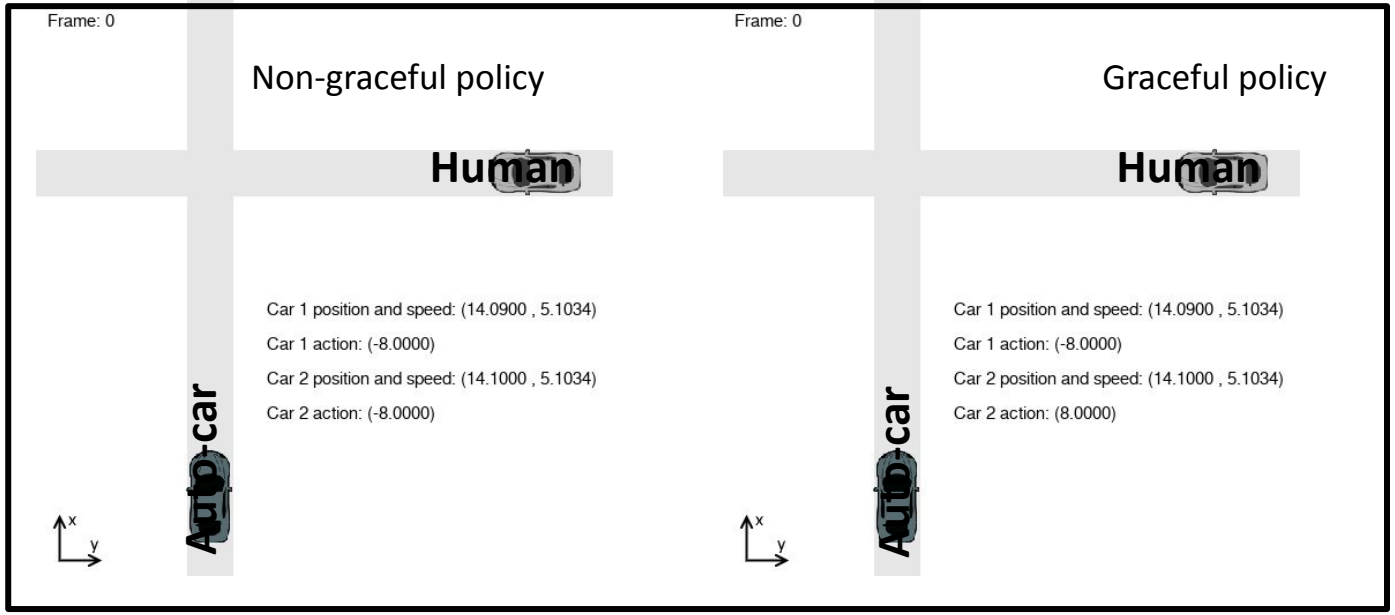


1. Chen, Y., Zhang, L., Merry, T., Amatya, S., Zhang, W., Ren, Y., "When shall I be empathetic? The utility of empathetic parameter estimation in multi-agent interactions", under review, 2021.
2. Wang, Y., Ren, Y., Elliott, S., Zhang, W., "Enabling courteous vehicle interactions through game-based and dynamics-aware intent inference", *IEEE Transactions on Intelligent Vehicles* 5 (2), 217-228 (2020)
3. Ren, Y., Elliott, S., Wang, Y., Yang, Y., Zhang, W., "How shall I drive? Interaction modeling and motion planning towards empathetic and socially-graceful driving", 2019 International Conference on Robotics and Automation (ICRA), 4325-4331

Ongoing work 2: Courteous interactions
Ongoing work 3: Validation data collection for reduced interaction graph

Courteous Interactions

- Courtesy requires adaptation of ego's equilibrial Hamiltonian according to the inferred private parameters of fellows
- Extending Hamiltonian approximation to the full intent distribution space is hard
- Insight: A courteous policy can be approximated by non-courteous equilibrial policies and courteous actions at specific states and time



Data for Reduced Interaction Graph

- Collected human gaze data during interactions to validate alg. for graph reduction based on equilibrial values

A heatmap demonstrating the driver's gaze behavior at an uncontrolled intersection when interacting with an AV

*Work in progress

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