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

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https://home.riselab.info/nri.html

Objectives: To improve the scalability, generalizability, robustness, and social adeptness of real-time intent inference and motion planning algorithms in collaborative robots (co-robots), with an application in autonomous vehicles

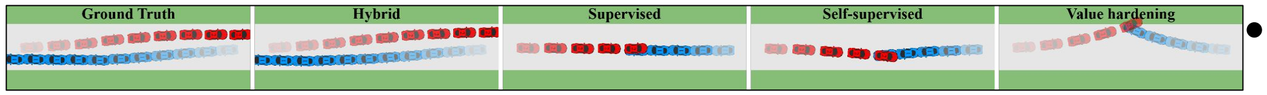
Challenges:

- Interactions are differential games w/ incomplete-information
- Computing perfect Bayesian equilibrium (PBE) in real time is computationally expensive
- Spatial sensing for real 3D environments is incomplete

Solutions: Theory- and data-driven PBE approximation, a detector-free and end-to-end Vision Transformer based one-stage multi-modal model

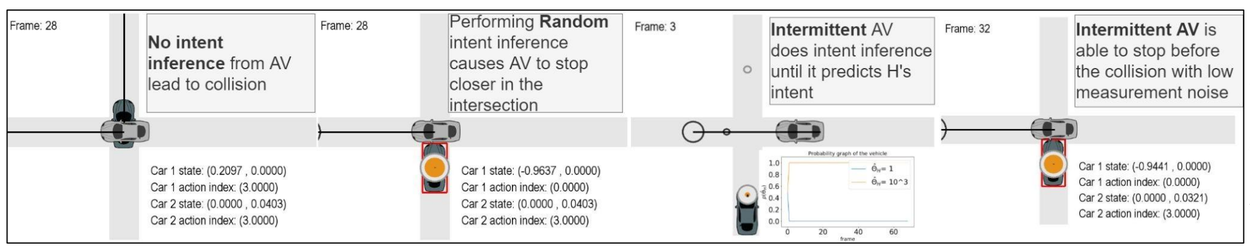
Result 1: Discontinuous Nash Equilibrial Value Approximation [1]

- Solving Hamilton-Jacobi-Isaacs PDEs suffer from curse of dimensionality (CoD) and have discontinuous solutions due to safety specifications
- Self-supervised (physics-informed) machine learning has been used to alleviate CoD in solving PDEs, but fail to converge to discontinuous solutions
- Hybrid learning leverages both supervised and self-supervised learning to approximate discontinuous values and show efficacy in two vehicle interactions



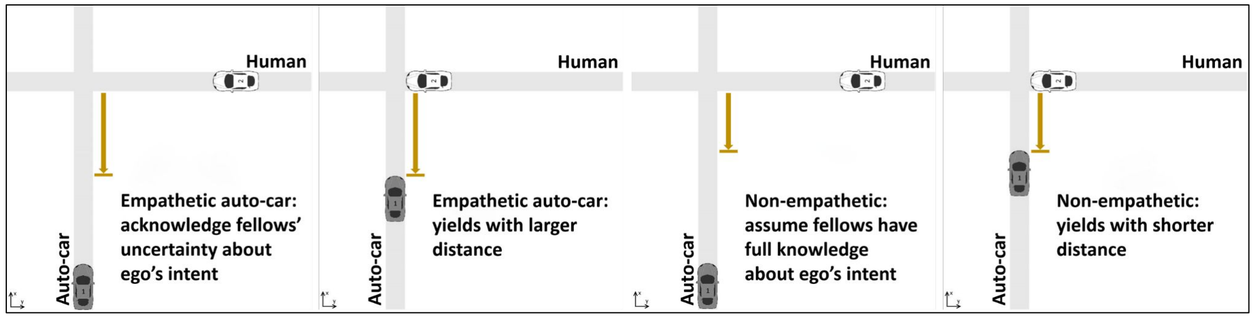
Result 2: Intermittent Empathetic Intent Inference [2]

- RL agent decides when to perform intent inference and thus is able to significantly reduce the computational costs and maintain safe interaction
- The proposed method is able to predict correct intent even in the presence of noise in the measurement



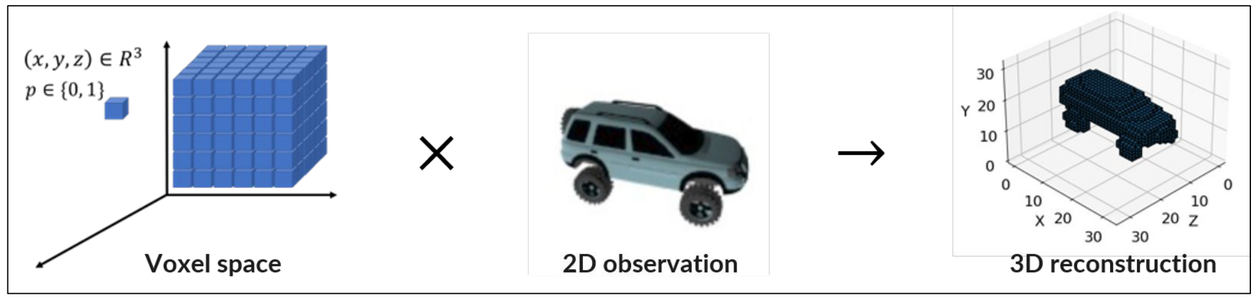
Result 3: Empathetic Intent Inference with Belief Uncertainty [3]

- Inference via bounded rationality, Bayesian belief update & equilibrial Hamiltonian approximation
- Hamiltonian incorporate belief uncertainty, approximated via learning of co-state dynamics
- Empathy improves intent inference accuracy, and interaction safety in turn, especially when agents have biased prior beliefs (e.g., not recognizing extremely aggressive drivers)



Result 4: Structure-aware Localization and Mapping

- By utilizing learning-based 3D reconstruction, SLAM is able to gain awareness of the environment's structure with only a few observations
- The structural information obtained through 3D reconstruction can enhance the robustness of both localization and mapping



1. *Zhang, L., Ghimire, M., Zhang, W., Xu, Z., Ren, Y., "Approximating Discontinuous Nash Equilibrial Values of Two-Player General-Sum Differential Games", ICRA2023*
2. *Amatya, S., Ghimire, M., Ren, Y., Xu, Zhe., Zhang, W., "When Shall I Estimate Your Intent? Costs and Benefits of Intent Inference in Multi-Agent Interactions", ACC2022*
3. *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", ICRA2021*

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Animation of results shown via QR code