NRI: FND: COLLAB:
Distributed, Semantically-Aware Tracking and Planning for Fleets of Robots

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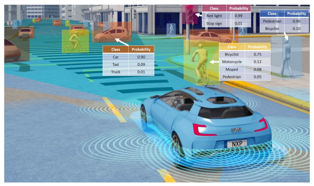
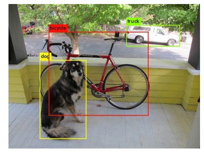
Goal

Enable safe and dependable operation of large-scale autonomous robotic fleets, such as autonomous vehicles and delivery drones, in complex and dynamic environments

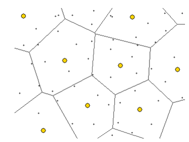


Key Problems

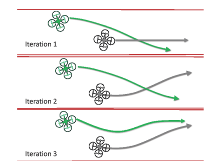
1. *Classify and track stationary, dynamic, and reactive objects in fast-paced dense urban environments*
   - *CNN-Based "Front End"*
   - *Investigate Three Semantic, Multi-Target Estimation "Back End" Architectures*



2. *Partition the environment and use this to distribute information across the team*
   - *Visibility-Aware Partition*
   - *Low-Bandwidth Communication*
   - *Robust Strategies for Data Integrity*



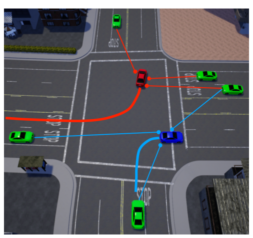
3. Predict a range of possible future target behaviors in order to plan safe actions
   - Planning For Reactive Interaction
   - Learning for Reactive Prediction

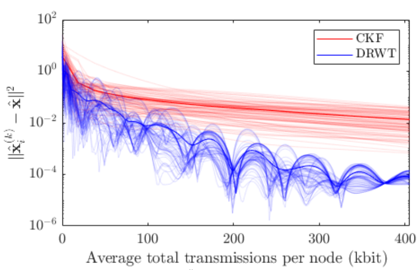


Significant Contributions

Distributed Multi-target Tracking Using Distributed Optimization

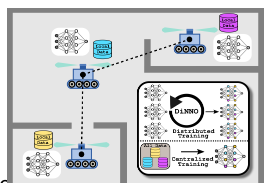
- Networked AVs communicate an optimize iteratively to track targets
- Faster convergence than distributed Kalman Filter algorithms



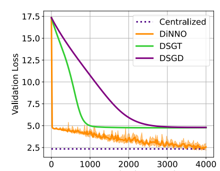


O. Shorinwa, T. Halsted, and M. Schwager, "Scalable Distributed Optimization with Separable Variables in Multi-Agent Networks," In Proc. of ACC 2020.

Distributed Neural Network Training for Robot Networks



- ADMM based framework for training deep nets in a multi-robot network
- Integrated with existing SGD training tools (e.g. in PyTorch)
- Achieves performance similar to centralized training

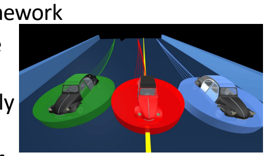


- Preserves data privacy
- Tested on distributed visual recognition, mapping, and multi-agent RL tasks.

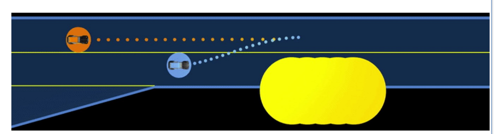
J. Yu, J. Vincent, M. Schwager, "DINNO: Distributed Neural Network Optimization for Multi-Robot Collaborative Learning," *RA-L*, 2022.

Game Theoretic Planning for Interactive Autonomous Vehicles

- Planning framework built on game theory to simultaneously predict trajectories of other vehicles and plan trajectory for own vehicle



- Fast numerical algorithm to re-solve trajectories online
- Inverse game theoretic planning for learning objectives of other players during interaction



S. Le Cleac'h, M. Schwager, and Z. Manchester, "ALGAMES: A Fast Augmented Lagrangian Solver for Constrained Dynamic Games," *Autonomous Robots*, 2022.

S. Le Cleac'h, M. Schwager, and Z. Manchester, "LUCIDGames: Online Unscented Inverse Dynamic Games for Adaptive Trajectory Prediction and Planning," *IEEE Robotics and Automation Letters*, vol. 6, no. 3, pp. 5485–5492, 2021.

Broader Impacts

Societal Impact

- Potential for greater mobility of people and goods
- Reduction in traffic congestion
- Increased safety in human-filled environments

Education and Outreach

- Student mentorship in lab at UG, MS, and PhD levels
- Senior design capstone projects
- Laboratory tours for K-12 students, visiting faculty, industry workers, etc.
- Inclusion in courses at Temple and Stanford

2022 NRI & FRR Principal Investigators' Meeting
March 19-21, 2022

Award ID#: IIS-1830419 (Temple)
IIS-1830402 (Stanford)