Bachelor/Master Thesis

Imitation Learning From Optimization-Based Motion Planners for Autonomous Driving

Problem Statement

In the realm of autonomous driving, motion planning holds a critical role, generating a sequence of waypoints or commands to navigate a vehicle from its present location to a target destination. A popular strategy for optimization-based motion planning is model predictive control (MPC). MPC's strength lies in its proactive planning capability, allowing it to adjust its plans to evolving traffic conditions by anticipating the ego vehicle's future states based on its current ones. This predictive accuracy is intimately tied to the fidelity of the vehicle's dynamic model. However, a more intricate model, while enhancing prediction accuracy, also brings a surge in computational demands. Additionally, the need for collision-free trajectories adds safety constraints to the optimization problem, increasing its nonconvexity and thereby amplifying the computational demand. Consequently, even a moderate prediction horizon can overwhelm real-time computational capacities in dynamically shifting driving conditions.

Imitation learning (IL), a machine learning method, proposes a compelling solution. In IL, a model is trying to learn a policy (a mapping from states to actions) from demonstrations of experts – an MPC-based motion planner in this context. Once adequately trained, this IL-based motion planner can replicate the behaviors of its MPC counterpart while substantially reducing computational costs. Yet, a significant challenge persists: guaranteeing the safety of IL-based motion planners. This concern is magnified when neural networks, especially deep architectures, are used in IL, whose opaque decision-making mechanisms can obscure safety assessments.

Your Tasks

- **Data Collection**: Use our MPC-based motion planner [1] to generate a rich training dataset with a diverse range of scenarios
- **Design and Training**: Following established methodologies such as [2], design and train an IL-based motion planner to imitate the behavior of our MPC-based motion planner (this entails selecting an appropriate neural network architecture, defining the loss functions, and training/testing the model)
- **Safety Guarantee (only for master thesis)**: Propose and implement techniques to guarantee the safety of the trajectories generated by the IL-based planner (this might involve hybrid approaches combining IL- and MPC-based planners, see [2] as an example, or post-processing verification checks, as in [3])
- **Evaluation**: Compare the real-time capability, trajectory optimality, and safety of the IL-based planner against the original MPC-based planner in various driving scenarios

Your Profile

- Study Computer Science, Automation Engineering, Mechanical Engineering, or a similar study program
- A keen interest in motion planning and machine learning
- Familiarity with motion planning/machine learning/MPC is advantageous

Contact

Please read our Instructions for Applications.

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[1] Scheffe et al. – 2023 – Receding Horizon Control Using Graph Search for Multi-Agent Trajectory Planning
[2] Sun et al. – 2017 – A Fast Integrated Planning and Control Framework for Autonomous Driving via Imitation Learning
[3] Chen et al. – 2019 – Deep Imitation Learning for Autonomous Driving in Generic Urban Scenarios with Enhanced Safety