AUTONOMOUS ROBOTS LAB

Safe Reinforcement Learning for visual Navigation using Control Barrier Functions

Abstract: Autonomous robot navigation in cluttered environments poses an entire spectrum of challenges to any navigation stack. To overcome issues related to traditional navigation approaches using a full map to plan and execute actions, we consider a class of learned visual control policies to generate feasible actions based on exteroceptive sensor data such as depth images or LiDAR scans. Reinforcement Learning (RL) has successfully applied to such tasks previously [1], but the pertinent issue of safety of the learned control policy remains. In This work, we investigate the use of Control Barrier Functions within the training process as in [2] to guarantee safety of the learned policy for visual navigation tasks with high-dimensional input data. By using certificate functions such as CBFs to guide the training process, high levels of constraint satisfaction can be achieved.

Tasks:

- Study and understand relevant methods in the RL literature such as Dynamic Programming, Proximal Policy Optimization (PPO) and Actor-Critic Methods
- Understand the working Principles of CBFs, in particular Zeroing Control Barrier Functions and Exponential Control Barrier Functions (ECBF).
- Familiarize with the Aerial Gym Simulator (github.com/ntnu-arl/aerial_gym_simulator) for parallel GPU accelerated rollouts and sample collection.
- Integrate CBFs with the RL formulation for navigation using low-dimensional range sensor
- Train a network model with the resulting formulation in simulation
- Test and deploy the resulting control policy on a small aerial robot

Literature (indicative):

[1] Kulkarni et al., Reinforcement Learning for Collision-free Flight Exploiting Deep Collision Encoding, 2024, ICRA 2024

[2] Cheng et al., End-to-End Safe Reinforcement Learning through Barrier Functions for Safety-Critical Continuous Control Tasks. *Proceedings of the AAAI Conference on Artificial Intelligence*, *33*(01), 3387-3395.

Main supervisor: Kostas Alexis, Professor, NTNU | **Co-supervisor:** Marvin Harms (PhD Candidate)