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Title

Navigation in Non-Static Environments with Autonomous Drones: A Kalman Filter Reinforcement Learning Approach

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Abstract

Over the last decade, autonomous drone systems' use has significantly increased in various industries, such as surveying and search-rescue. These systems rely on multiple algorithms for trajectory planning, which are designed to navigate in different environments. However, most of the algorithms developed for trajectory planning are intended to be used in static environments, where all objects other than the autonomous vehicle remain fixed during the system's operation. One of the significant challenges when working with autonomous drone systems is the dynamic nature of the environment. When the environment is not entirely static, it requires the implementation of different algorithms for various tasks such as object detection, state estimation, and trajectory planning. These algorithms must be able to accurately detect and track the moving objects, estimate their state, and plan a trajectory that avoids collisions while still reaching the goal object. This is a complex task that requires advanced techniques and algorithms. State estimation in model predictive control for trajectory planning of autonomous drones in dynamic environments can be challenging, as two main problems need to be addressed:

- Continuous Action Spaces: The action space for controlling the drone's trajectory is continuous and high-dimensional, making it challenging to find the optimal policy using traditional techniques.
- Uncertainty and Non-Stationary Environments: The drone's environment is highly dynamic and uncertain, making it challenging to predict the system's future state and plan a trajectory that avoids collisions.

The solution proposed in this paper combines a variation of the Kalman Filters for state estimation under uncertainty and Advanced Actor-Critic Reinforcement Learning (RL) Algorithms to estimate the best feasible trajectory. In the simulated scenario, the Kalman Filter estimates the centroid of the closest movable target (gate) and predicts the position in the space of the same object in the next time step. The RL agent uses this information to estimate the best trajectory. RL algorithms use a trial-and-error approach to learn the optimal policy by exploring different actions and receiving feedback in the form of rewards. In this paper, three algorithms have been explored: Deterministic Policy Gradient (DDPG), Soft-Actor Critic (SAC), and Proximal Policy Optimization (PPO) to evaluate how different approaches to the same problems perform in comparison. These algorithms are well-suited for trajectory planning tasks in dynamic environments as they can handle continuous action spaces, uncertainty, and non-stationary environments. Combining Kalman Filter and Reinforcement Learning, the overall performance of the trajectory planning and subsequent navigation action decision-making have shown significant improvements in executing the navigation task by allowing the drone to navigate the simulated dynamic scenario successfully. Furthermore, the proposed approach has been developed to work in a continuous state-action environment, which means that the state of the system and the actions taken by the agent are continuous variables in complete analogy with what happens in the real world. This allows for more flexibility and precision in controlling the drone's trajectory.