Decentralized Control Policy with Imitation Learning for Multiple Multirotors Transporting Cable Suspended Payloads

MSc Thesis Topic

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1 Abstract

Uncrewed aerial vehicles (UAVs) are ideal for robust autonomous tasks that involve accessing remote locations, shipping objects or executing construction tasks. The agility of the multirotors allows them to collaboratively execute complex applications such as carrying a payload in uncertain environments being transported by cables. This application is extremely beneficial at construction sites for rubble removal in search-and-rescue scenarios, and nuclear power plant decommissioning.

In dynamic environments, centralized control algorithms typically manage all robots from a single point, providing precise coordination. However, this comes at the expense of communication overhead and notable scalability challenges. Centralized optimization-based controllers, like nonlinear model predictive control (NMPC), have been developed to control multirotors transporting payloads while avoiding collisions [1], [2]. However, these methods often face scalability limitations due to the exhaustive computational demands they impose.

Classical decentralized control algorithms address these issues by distributing decision-making among multirotors, enhancing scalability and resilience [3], [4]. However, Some of the devised control algorithms do not include collision constraints, or they often struggle with the problem of local minima and deadlocks.

In our previous works [5], [6], we have developed a methodology that integrates a centralized offline motion planner with a decentralized controller, designed to transport a point mass using multiple aerial multirotors through environments cluttered with obstacles. This hybrid approach addresses the limitations of purely centralized and decentralized controllers by leveraging the comprehensive planning capabilities of the centralized solution and the adaptive execution of the decentralized controller. However, this strategy is primarily effective in static environments, as it relies on following a pre-determined, offline plan and lacks the flexibility to adapt to dynamic changes. Moreover, while the decentralized controller is efficient, it simplifies the inter-robot collision problem by convexifying the constraints, which can sometimes lead to infeasible solutions.

Imitation Learning (IL) can replicate the strategies of an expensive planner [7], [8], effectively substituting the optimal control or planning solver with a function that approximates these solutions. The **goal** of this thesis is to utilize imitation learning using DAGGER to develop a decentralized control policy for the multirotors transporting a pointmass payload that overcomes the limitations of local minima. Specifically, we use a centralized kinodynamic motion planner as the global policy (the expert), which the local policy aims to emulate. The process begins by generating feasible trajectories [6] for various motion planning scenarios and environments. Subsequently, a local observation model is employed to compile a dataset of observation-action pairs. Finally, we apply imitation learning to create a local policy that mimics the global expert, thereby avoiding local minima. The imitation learning control policy will be compared to two baselines: the full framework of the previous works [5], [6] and the nonlinear model predictive control of the payload system.

2 Milestones

1. literature review: imitation learning in decentralized control policies for multi-robot systems.
2. implement the nonlinear model predictive controller for the multiple payload transport system in simulation.
3. generate a dataset in simulation for multiple multirotors transporting the payload in random environments with obstacles using the expert planner in [6].
4. train Deep Neural Networks (DNNs) using DAGGER fora a decentralized control policy for multiple multirotors transporting a payload.
5. benchmark the policy against the baselines using multiple metrics (e.g., success, energy, tracking error).
6. test the policy on the real platform with multiple (two or three) multirotors and a payload in different environments (**optional**).

References

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