WS 2022-2023, SMT-ROB, DISAL-MP49 Project Summary

Design and Analysis of Modular and Scalable Model Predictive Control for MAVs Performing Formations

Shashank Mahendra Deshmukh

Professor : Alcherio Martinoli
Assistant : Kagan Erünsal

With the rapid development in communication technologies, networked multi-vehicle systems have received increasing attention over the last decades. A particular application hereof is the formation control of multi-vehicle systems. The aim of this project is to design a scalable formation controller that is modular in structure and ensures global stability. The performance is evaluated in MATLAB simulation.

In the scope of formation control, the current contributions in the literature have a fixed number of vehicles in the network and do not handle network modifications. Our objective is to propose a controller that allows systems to join and leave with minimal supervision effort and performance degradation. We have employed MPC as its ability to handle explicit constraints and provide stability and feasibility guarantees of the system. We implemented a distributed MPC since the centralized one is not scalable and compared to decentralized one it is better able to estimate the global objective. In particular, we designed a cooperative distributed MPC that iteratively communicates per time step to optimize the central MPC via distributed optimization using ADMM. The proposed method relies on a distributed invariance based on structured time-varying terminal sets that are synthesized and updated during online operation. In case of network modification requests, we first redesign the local controllers according to the modified network and synthesize local terminal laws in a distributed manner and check the feasibility of the local controllers at the current system state. If permissible, we modify the local controllers and perform formation with a modified network, else the request is rejected. This is summarized in Figure 1.

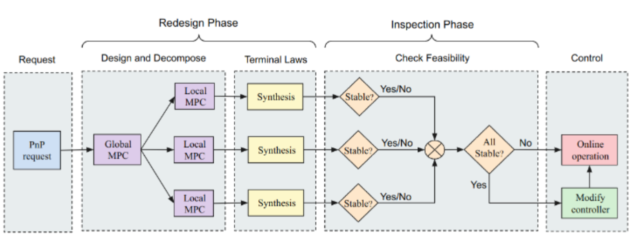
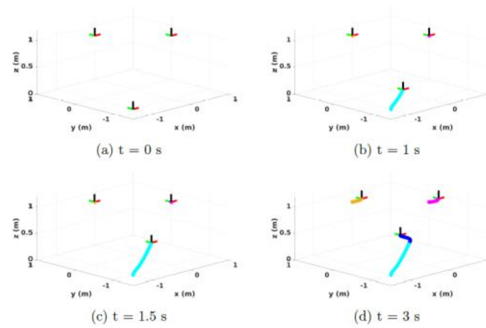


Figure 1: Plug and Play operation

In Figure 2, we can see that the drones start at t = 0s, then the incoming drone proceeds to approach a drone in the current network until t = 1.5s, which is when the modification request is initiated. Finally, once this request is permitted, formation control with the modified network is performed till t = 3s. Note the color of new



drone's path changes indicating the moment when the network was modified.

Figure 2: Trajectories for 3-drone case. Magenta and orange correspond to the existing drones and blue to the new drone.

Upon testing for various cases and scenarios, we observed that the communication rates increase with the number of neighbors. Regarding solver times, we see that it decreases as the formation converges and the proposed method has a weak correlation with the number of neighbors and is nearly independent to the network topology. This is due to the reason of using an average-based controller formation model. The performance as a group depends on the network topology with faster convergence for lesser number of drones in the network or more redundant connections in the topology. Moreover, the results also show that by adding terminal conditions the performance becomes more conservative in nature.

Finally, this thesis presents a design method for scalable and distributed formation control that is capable of handling network modifications online. The MATLAB simulation results demonstrate how, by taking advantage of inter-robot communication, we can ensure the feasibility and stability of the global system without compromising much on the overall performance.