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DISTRIBUTED ROBUST CONSENSUS-BASED CONTROL WITH COLLISION AVOIDANCE FOR SATELLITE FORMATION FLYING

Abstract

Multi-satellite systems are getting more and more prominent in recent years. They enable various new application areas from distributed communication networks and science missions (like distributed magnetosphere measurements as performed by the MMS mission) as well as close-range applications (like in-orbit inspection or assembly). Even among CubeSats there are examples of distributed satellite systems like the NetSat mission, which aims at demonstrating formation control of 4 CubeSats in late 2019 and the TOM mission, which will use a CubeSat formation to perform multi-perspective ash cloud monitoring in 2020.

These new applications demand suitable control methods, especially for close-range satellite formation applications, which impose the highest demands. Control approaches that are both distributed and robust are required. Distributed to be scalable, fail-safe and to achieve a common goal. Robust to guarantee stability in the presence of uncertainties like sensor noise, disturbances, actuator errors and orbit perturbations.

This paper presents a combination of robust H-infinity control and distributed control using consensus approach. A distributed consensus-based generalized plant description has been derived that includes disturbances as well as noise on each satellite and that suits the requirements for H-infinity synthesis. By applying H-infinity synthesis individual controllers for all satellites in a specific formation setup can be computed that guarantee robustness with respect to the given uncertainties and that work in a distributed manner. This is guaranteed by using the consensus approach which enables the satellites to follow a common goal (reaching a specific formation configuration) and to pursue the common goal even if any of the satellites fails. In addition to describing the principles of of this approach, special focus is set on the development of a potential field based collision avoidance method and its implementation within the controller, since collision avoidance is of major importance especially in close-range formation flying.

Simulations based on a realistic scenario from the NetSat CubeSat mission are presented that show the applicability of the developed distributed robust control method to a realistic space scenario, as well as the additional safety provided by collision avoidance, which is demonstrated in a specific scenario.

The developed distributed robust control approach allows to control an arbitrary number of satellites towards an arbitrary formation geometry in a distributed manner while avoiding collisions among the

satellites. Because of the combination with robust H-infinity control, the presented method satisfies the high stability and robustness demands as found in space applications.