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Author: Mr. Enrico Belloni
Politecnico di Milano, Italy

Mr. Francesco De Cecio
Politecnico di Milano, Italy
Prof. Michèle Lavagna
Politecnico di Milano, Italy

AUTONOMOUS GUIDANCE, NAVIGATION, AND CONTROL FOR CLOSE FORMATIONS THROUGH SEQUENTIAL CONVEX PROGRAMMING AND INTER-SATELLITE RANGING

Abstract

A trending topic for future space missions is to distribute complex tasks among several agents, instead of relying on large monolithic spacecraft. A typical scenario of such an approach is represented by in-orbit assembly or interferometry-based missions like distributed antenna systems or telescopes. In these scenarios, the acquisition and maintenance of the formation geometry becomes a critical aspect to be addressed that cannot be solved with traditional ground-based techniques. Hence, the development of novel and autonomous guidance, navigation, and control techniques plays a driving role in enabling these new mission concepts.

The usual approach to research on the topic is to treat guidance and control separately from navigation. However, this practice requires the formulation of several assumptions on expected state estimation accuracies and may lead to an oversimplification and incomplete understanding of the problem. In this paper, distributed algorithms are explored to accomplish both tasks in an organic and cooperative manner, trying to investigate all the key challenges of the problem.

Therefore, an innovative strategy for the relative state estimation and control of large spacecraft formations is proposed, based on a convex model predictive control strategy and radiofrequency navigation via inter-satellite link. More in detail, the guidance and control of the distributed system are addressed with sequential convex programming techniques that allow the computation of optimal control profiles for the formation considering goal-oriented objectives and safety-related constraints in a computationally efficient algorithmic routine. On the other hand, the selected navigation technique exploits a radiofrequency network architecture established between agents based on code division multiple access. Both range and range-rate measurements are obtained through a GNSS-like signal transmitted by each agent. Employing multiple receivers, line of sight estimates can be also retrieved. Moreover, this network can be used as a time and data distribution system, useful for mission scientific objectives. A real-time estimate of the formation state is thus obtained without additional, dedicated navigation sensors.

The proposed distributed design optimizes both the computational effort spent by each agent for formation keeping and the achievable performance while retaining with higher fidelity the features of the problem like noisy, asynchronous measurement collection and clock synchronization between agents. The onboard implementability of the developed strategy is facilitated by utilizing library-free coding in an embedded system programming language. Furthermore, Monte Carlo analyses are performed to assess the robustness of the proposed formation-keeping loop.