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ROBUST TRAJECTORY PLANNING FOR MULTIPLE SPACECRAFT WITH ELECTRIC PROPULSION

Abstract

In order to meet the increasing complexity and budget limitation of missions in space exploration, it is necessary to let multiple low-cost spacecraft equipped with electric propulsion collaboratively complete challenging tasks. Successful enablement of such critical capabilities needs real-time implementable, flexible, and robust path planner for multiple spacecraft system with model uncertainties, disturbances and a large class of constraints, such as converging to the desired configuration, maintaining the exchange (formation) among them, avoiding collisions both with each other and with obstacles, and the maximum available thrust.

To address these challenges, specifically when multiple spacecraft fly in near-circular orbit, this paper focuses on combining the strengths of several approaches in the field of motion planning. First of all, through incorporating splines parameterization to rapidly exploring random tree (RRT) algorithm (we call it Spline-based RRT), initial reference trajectories for spacecraft are generated. The main advantage of Spline-based RRT is that it enables the constraints for multiple spacecraft system to be handled efficiently and the computationally expensive numerical integration of the system dynamics to be avoided. During the planning process of Spline-based RRT for an individual spacecraft, the allowable distances from the trajectory of the virtual leader (desired trajectory) and its neighbors are treat as another type of restriction. This can be viewed as multi-object motion planning and contributes a lot to the formation maintaining. Then, to make sure that the trajectories are robust to disturbances and uncertainties and also more feasible for spacecraft, idea from distributed model predictive control (DMPC) method is used to track reference trajectories for multiple spacecraft in real-time over a finite-horizon, while refining the remaining part of the trajectories and estimating the disturbances and uncertainties.

To the best knowledge of the authors, in this paper, robust trajectory planning problem for multiple spacecraft with electric propulsion under model uncertainties, disturbances and constraints is solved for the first time. As an application of this trajectory planning framework, we consider a reconfiguration problem of three 3U CubeSats equipped with electrospray thrusters flying in near-circular orbit, at an altitude of approximately 450km, and in presence of several obstacles. Simulation results demonstrate that the proposed approach can efficiently generate robust trajectories for multiple spacecraft system and is well suited for real-time implementation.