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Author: Mr. Maximilian Walther
Institute of Space Systems, University of Stuttgart, Germany, st142890@stud.uni-stuttgart.de

Mr. Constantin Traub
Institute of Space Systems, University of Stuttgart, Germany, ctraub@irs.uni-stuttgart.de
Prof.Dr. Georg Herdrich
Institute of Space Systems, Germany, herdrich@irs.uni-stuttgart.de
Prof. Stefanos Fasoulas
Institute of Space Systems, University of Stuttgart, Germany, fasoulas@irs.uni-stuttgart.de

IMPROVEMENTS OF THE FEASIBILITY RANGE OF RENDEZVOUS MANEUVERS USING AERODYNAMIC FORCES

Abstract

Several small unconnected satellites flying in formation are a frequently discussed option to replace large satellites due to advantages such as increased flexibility, reduced costs and enhanced reliability. Using differential aerodynamic forces as a means to maintain the formation despite present perturbations, to perform formation reconfiguration or to initiate a rendezvous maneuver is a promising propellant-less alternative to chemical and/or electric propulsion systems.

Subjected to uncertainties, dynamic variations and non-linearities its implementation in a real mission is, however, challenging. A common practice to either design suitable reference trajectories for robust control strategies or to gain deeper insights into the methodology is to use linearized relative motion models and a constant density assumption. Following this practice, multiple previous studies developed and enhanced analytic control algorithms to zero out the relative position and velocity of two spacecraft utilizing differential aerodynamic forces. Even though aerodynamic lift expands the controllability to all three translational degrees of freedom, it has been frequently neglected due to the low lift coefficients experienced so far. And even if considered, analysis has shown that the feasibility domain of using differential lift for the eccentricity control of the in-plane motion is extremely limited compared to using differential drag.

However, two different possible options, namely applying enhanced algorithms to decrease the eccentricity before even initializing the eccentricity control phase as well as using advanced satellite surface materials targeting specular or quasi-specular reflection and thereby increasing the differential lift forces, have been suggested to increase the feasibility domain of the methodology.

In this paper, the effectiveness of the proposed adjustments is analyzed in a Monte Carlo approach by applying them to the analytic control algorithms introduced in literature. Since these are based on the linearized Schweighart-Sedwick equations, so is the presented analysis. Moreover, additional modifications to the algorithms are made to reduce the maneuver times of respective control phases.

The results show that the analyzed options noticeably improve the success rates of the maneuvers. Especially the feasibility range of the lift-based control algorithms is enlarged considerably. In addition, the implemented modifications are shown to consistently reduce the maneuver time of the respective control phase. Consequently, the presented analysis improves the current state of the art of the analytically designed rendezvous trajectories and provides valuable new insights into the methodology of using differential aerodynamic forces as a means of relative motion control.