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# NONLINEAR CONTROL WITH J2 AND DRAG PERTURBATIONS FOR NANOSATELLITE FORMATION FLIGHT

**Abstract**

The Telematics Observation Mission (TOM) is a formation flying mission for joint earth observation with three nanosatellites. One of the major challenges to be addressed is an orbit control system for formation acquisition and keeping, while accounting for non-linearities and disturbances.

This paper presents the design of formation flying (FF) control system for low Earth orbit (LEO) satellites based on the State-Dependent Ricatti Equation (SDRE) control approach. Most control approaches to FF are based on the Hill-Clohessy-Wiltshire model of linearized equations of relative motion. Studies on FF control using the nonlinear equations of relative motion (NLEoRM) have already been conducted, however the disturbance forces like J2-perturbations are usually linearized. In this paper a novel approach to incorporating nonlinear relative J2-perturbations in FF control using the SDRE technique is developed using nonlinear equations of relative motion.

Several State Dependent Coefficient (SDC) formulations of the NLEoRM are devised and evaluated for performance with regard to formation acquisition time and control effort. These formulations are chosen so as to avoid having the velocity states in the denominator of any of the terms in the SDC matrix. This is to ensure that the SDC matrix does not have terms approaching infinity causing the control loop to collapse as the relative velocities may be required to be zero or very small in some formation flying scenarios. On the other hand, relative positions must not reach a zero value in formation flying unlike rendezvous and docking missions. The optimality of the SDRE control is dependent on the SDC formulation chosen. The additional degree of freedom associated with the SDC parameterizations can be exploited using a variable $\alpha$ that generates several other SDCs in the hyperplane of any two chosen SDCs. The variable $\alpha$ is then optimized to achieve near-optimal control. An optimal SDC formulation is then obtained for a predefined formation scenario.

The performance of these SDC formulations are evaluated through numerical simulations for a leader-follower formation acquisition in low Earth orbit. The results of fuel consumption and time acquisition are presented for each controller over several orbital periods (LEO). Furthermore, the control effort is mapped to the performance of UWE-4's (University Würzburg Experimental Satellite 4) in-orbit tested electrical propulsion unit for evaluation of power consumption which is of prime concern for nanosatellites.