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ROBUST FORMATION CONTROL IN LOW-EARTH-ORBIT USING SECTOR BOUNDS FOR J2 AND DRAG DISTURBANCES

Abstract

In recent years, driven by the miniaturization and increasing power efficiency of satellite core components, computing units and mission payload instruments, the so called new space development has seen a trend of cooperating small satellites, down to nano or pico satellite scale, being used for space missions that were previously only possible with single monolithic big satellites. This has been demonstrated with great success for example by Planet Labs with their earth observing dove cube satellite constellation. In contrast to constellations, where each satellite is independently controlled from the ground, formations increase the degree of inter-satellite cooperation and allow the satellites to adapt their relative positions autonomously, independent from ground contact windows. Such a control structure paves the way for a plenitude of new missions for nano satellites. Examples of such future missions are the distributed simultaneous observation of vulcanic ash clouds to determine their 3D structure or the determination of the internal composition of regular clouds by recording and analyzing the spacial distribution of the scattered light from the cloud in the Cloud-CT project. Earth observation missions like the a fore mentioned usually operate in Low Earth Orbit (LEO) as it provides beneficial qualities for such missions, like a lower required transmit power for ground communication in comparison with higher orbits. An integral part of a formation of satellites is the control of relative satellite distances using the propulsion system aboard the satellites. Most such control approaches rely on a linearized representation of the relative satellite motion, the Clohessy-Wiltshire model. The nominal motion in this model is mainly perturbed in LEO by the J2 effect, drag and the deviation of the reference orbit eccentricity from a perfect circular orbit. Approaches which explicitly take these disturbances into account, often rely on extended non-linear motion models which leads to extensive required run-time computations for the control, e.g. SDRE based methods. To address both the computational complexity and cope with these disturbances, we propose a robust gain state feedback formation control approach, that guarantees stability and convergence under sector bounded disturbances using a linearized relative motion model. The sector shape is optimized with respect to the effect of relative J2, drag and non-zero eccentricity. The control performance is validated in simulation using a high precision orbit propagator, incorporating J2, drag, elliptical orbits and additional perturbations, with formation objectives taken from the upcoming Netsat cube-sat formation mission.