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OPTIMAL COLLISION AVOIDANCE STRATEGIES FOR A SWARM OF NANOSATELLITES IN A REALISTIC SCENARIO

Abstract

In the last years, CubeSats have become one of the possible solutions for several space mission scenarios because of their low realization cost and accessibility to both industries and universities. Their low mass and high manufacturing repeatability, in conjunction with their reduced capabilities, suggest the employment of a swarm of CubeSats in which each agent contributes to accomplish the global mission task. Because of their reduced mass, power and computational availability, CubeSats are usually equipped with simple systems, such as single-axis thrusters and low accuracy sensors for autonomous navigation. As a matter of fact, those kinds of systems are more likely to present failures with respect to the more advanced ones that can be accommodated on-board of larger platforms. Higher chances of failures translate into higher probability of collisions between satellites of the swarm and therefore the development of simple and clever collision avoidance strategies becomes crucial. Following the importance of this aspect, this paper presents several techniques of collision avoidance purposely developed for nanosatellites swarms. The collision probability determination is achieved through the integration of the probability density function associated to the CubeSats relative positions, propagated ahead in the future to forecast a possible collision, over the uncertainty volume associated to the satellites position. In the presence of a possible collision (i.e., when the collision probability overcomes a certain threshold) a maneuver is performed to avoid the impact. Differently form standard scenarios, in which a satellite is asked to avoid being hit by debris, the techniques employed in formation can either take into account the single collision event and minimize the ΔV required to obtain a minimum miss distance or assess and consider the consequences of such maneuver over the formation behavior. While the former does not guarantee the optimality of any global index, the latter selects the CubeSat that must perform the maneuver and determines its intensity following a global optimal logic, which can be tailored to the specific mission architecture and requirements. The proposed study develops collision avoidance strategies purposely built for formation flying scenarios and tests them in several scenarios, which can also include the failure of the propulsion system of one or more satellites of the swarm, in order to assess the correct completion of the mission.