Paper ID: 68387
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (2) (2)

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ATTITUDE MANEUVERS OF A FLEXIBLE SPACECRAFT FOR SPACE DEBRIS DETECTION AND COLLISION AVOIDANCE

Abstract

In recent years, the steady growth of the space debris population has stimulated all the major space agencies to intervene to reduce the risk of catastrophic collisions with operational satellites. With this regard, international guidelines state that (i) space debris must be subject to accurate monitoring, for prediction of possible impacts, and (ii) satellites must be able to perform collision avoidance maneuvers when an impact is likely. This work addresses the problem of attitude maneuvering of a spacecraft equipped with two flexible solar panels, in response to an alert in two distinct operational scenarios: (a) detection of an approaching debris, and (b) collision avoidance of an impacting debris. In application (a) the approaching debris is assumed to be off a collision course with the satellite. As a result, the latter can track the debris, to provide supplementary observations (in addition to those given by ground stations) that allow improving the estimation of its trajectory. Instead, in scenario (b) an impact is predicted, therefore the satellite shall perform a collision avoidance maneuver. This is designed with the objective of minimizing propellant consumption, while ensuring a miss distance greater than a specified threshold value. This research considers the overall dynamics by modeling the spacecraft as a multibody structure, with the use of the Kane's method, which simplifies the process of deriving all the governing equations, while identifying their minimum number. Flexibility is introduced using a modal decomposition technique, under the assumption of small amplitude oscillations. In the two scenarios of interest, efficient strategies are introduced to rotate the solar panels, for the purpose of either maximizing their irradiation or minimizing their oscillations. Attitude maneuvers are driven by a nonlinear reduced-attitude control law that enjoys quasi-global stability properties, proven through the Lyapunov direct method, in conjunction with the LaSalle invariance principle. Actuation is modeled as well, by assuming the use of a pyramidal array of four single-gimbal control momentum gyroscopes. These devices are steered by means of a pseudoinverse law that includes singularity avoidance based on the singular value decomposition of the actuation matrix. Numerical simulations demonstrate that the agile attitude maneuvering strategies proposed in this study allow achieving the operational objectives in the two scenarios of interest, with limited elastic oscillations.