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PROSPECTS OF TOUCHLESS SPACE DEBRIS DETUMBLING USING AN ELECTROSTATIC PUSHER CONFIGURATION

Abstract

The relative attitude motion is studied between two charge controlled geosynchronous bodies being held at a predetermined along-track configuration. While body one, the space tug, is modeled with a spherical shape, the 2nd body, the large space debris, is assumed to be non-spherical and tumbling. To describe an electrostatic force and torque model of a non-spherical body the Multi-Sphere Method (MSM) is employed that uses a collection of finite spheres to represent a complex shape and analytically approximate the Coulomb interaction with other charged bodies. Further, the tug is modeled as having thrusters that both accelerate the two-body system and maintain a desired relative configuration. This scenario allows for simultaneous repositioning and detumbling of both large and small GEO space objects. Detumbling is critical for orbital servicing where rotational motions above one degree per second prohibit current docking solutions.

Prior work studies electrostatically detumbling a space object primarily in either a neutral nominal charge or a puller configuration where the debris and tug have opposite polarity charges. This paper focuses on challenges particular to a pusher configuration where the debris and tug have nominally the same charge. While the MSM modeling allows for fast and accurate approximations of the resulting electrostatic forces and torques between the two charged bodies, it quickly yields complex analytical expressions that are challenging to integrate into an analysis of the closed loop control performance. Instead prior work used first order approximations of the resulting electrostatic control to analyze the stability.

This paper investigates a Lyapunov optimal control approach where the MSM electrostatic torque prediction can be directly incorporated into the detumble feedback control component. An advantage of the direct MSM integration into the feedback control law is that a range of MSM model fidelities can be considered. Induced charge effects are important if the space objects are separated by only 1-2 craft radii. However, with larger separation distances the mutual capacitance considerations are less significant. Further, the closed loop stability analysis of doing simultaneous pushing and detumbling is investigated to study both rate rejection and relative heading convergence. Only in-plane relative motion of the tug and debris are considered to focus on planar relative heading control and the impact of the MSM modeling within the control formulation. Numerical simulations illustrate how the parameters of the bodies and the control impact the stability of the system.