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PRECISE SPIN SYNC SLEW CONTROL BASED ON NONLINEAR OPTIMIZATION FOR SPINNING SPACECRAFT

Abstract

This paper aims to address the challenge of performing precise spin-axis reorientation maneuver for spacecraft (e.g. kinetic planetary penetrators) spinning about its minimal inertia (or major) axis using a single body fixed attitude control thruster, which takes into account constraints of dynamics, phase boundary and slew time, etc. Spin stabilization is an attractive way for providing attitude pointing stability to a spacecraft due to its simplicity and ability to reject against various disturbances, such as gravity gradient disturbance torque and liquid sloshing disturbance torque. This is deemed applicable to various missions involving upper stages, multiple unit CubeSats, and kinetic impactors such as for MoonLITE and NEOShield projects. Furthermore, for spinners using one attitude control thruster that is perpendicular to the spin axis is theoretically feasible and advantageous in terms of simplicity and redundancy in comparison to 3-axis stabilization control.

Spin Sync slew algorithm is recently developed for the single thruster attitude control of spinners. It possesses similar characteristic as Rhumb Line slew, but can be implemented to overcome the inherent singularity of the Rhumb Line slew and sun sensor failure. Both Spin Sync and Rhumb Line slews still have issues with residual nutation angle and potential divergence of the angular momentum trajectory. In this paper, a geometric method is proposed to estimate and compensate the angular momentum vector divergence. In addition, the paper presents solutions to achieve precise attitude control using the slews. This is a difficult problem due to nonlinear and nonconvex attitude dynamics and constraints and is hence treated as a nonlinear multi-phase optimal control problem with constraints related to initial and terminal state, control torque magnitude, attitude dynamics, and slew time. Here, the optimization is achieved by direct transcription using Gauss pseudo-spectral method, in which the varying boundary problem is converted to a fixed boundary problem by varying optimization parameters. Computer simulations and results are provided to demonstrate the proposed approach. The optimal control achieved is also verified using engineering software simulator of 'Attitude Control Simulator for Spinning Spacecraft with Single Thruster'.