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AUTONOMOUS NAVIGATION AND GUIDANCE FOR CUBESATS TO FLYBY NEAR-EARTH ASTEROIDS

Abstract

Asteroid flyby trajectories with minimal ΔV requirements can be designed from the vicinity of the Sun-Earth Lagrange points. If deployed around these points, current propulsion systems for CubeSats can provide the necessary ΔV to flyby a near-Earth asteroid, and therefore a new opportunity for the low-cost exploration of planetary bodies arises.

While technology advancements and favorable dynamics potentially enable these flyby missions, ground operations costs associated to deep-space travel still represent a major challenge for interplanetary CubeSats; hence certain levels of autonomy are desirable. In search of a low-cost solution to flyby near-Earth asteroids, this work studies the possibility of performing autonomous interplanetary navigation and guidance using CubeSats.

Considering the limited allocation of sensors and actuators in CubeSats, and their limited performance, fast-computation Monte Carlo simulations are implemented to understand the flyby accuracies that can be achieved autonomously. Primary sources of error considered in this analysis include: (1) uncertainties in the departure conditions, (2) errors in pointing knowledge and accuracy, (3) errors in the propulsive maneuvers, (4) errors in the observations, and (5) uncertainties in the ephemeris of the target asteroid.

The feasibility of various autonomous navigation and guidance strategies is assessed, for instance: (a) varying the type and frequency of observations (e.g., observations of the Sun, visible planets and/or of the target asteroid), and (b) performing only one or several trajectory correction maneuvers.

This sensitivity analysis is performed for three kinds of flyby trajectories (departing from the Sun-Earth Lagrange points): (1) impulsive, (2) quasi-impulsive (i.e., considering a more realistic thruster model), and (3) low-thrust trajectories—thus covering the primary types of propulsion technologies currently available for CubeSats.

Finally, a parametric study of the problem is performed to understand the impact of component performance in the resulting flyby accuracies, depending on: (a) pointing knowledge and accuracy, (b) performance of the thruster, and (c) quality of the observations.

The overall goal of this work is therefore to assess the readiness level of current CubeSat technology to autonomously flyby near-Earth asteroids. This study provides a comprehensive analysis of autonomous navigation and guidance strategies, component performance, and propulsive capabilities. If proven feasible, interplanetary CubeSats could provide a low-cost solution for the exploration of small planetary bodies, reducing not only the development and implementation costs of space missions, but also deep-space ground operations costs.