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ROBUSTNESS ASSESSMENT OF ASTEROID APPROACH TRAJECTORY REGARDING THRUSTER FAILURES AND MISSED MANEUVERS

Abstract

Among the recent missions for space exploration, Near Earth Objects (NEOs) have been privileged targets for scientific activities. In fact, these bodies are of great interest as they are geological remnants of the early solar system but also potential threats that might collide with the Earth. As a result, multiple spacecrafts have been sent around these objects to perform measurements and *in-situ* sampling.

However, reaching NEOs has been revealed to be a challenging task. The low gravitational field and the many perturbations, such as Solar Radiation Pressure (SRP) or other bodies' attraction, make it difficult for a spacecraft to navigate accurately in this environment. Moreover, mission design and requirements can constrain the trajectory, with for instance specific positions to reach or maneuvers to perform. Therefore, thruster malfunctions might have a critical impact on the spacecraft's complex motion and prevent the mission from success.

Consequently, safety considerations must be included in trajectory design along fuel consumption optimization and mission constraints. Safe trajectories have been extensively investigated during the past decades for spacecraft rendezvous and docking in Earth orbit, interplanetary transfers and trajectory recovery. Different approaches have been developed, exploiting various metrics to assess the flight path reliability or sensitivity to misfires.

While previous studies addressed the problem of trajectories robust to thruster failures in the previously mentioned frameworks, this work extends the analysis to approach trajectories to NEOs, meant to reduce the relative distance to a few kilometers. The developed methodology is applied to the OSIRIS-REx spacecraft study case, encountering asteroid Bennu. In the nominal case, a sequence of waypoints to reach is defined. A reference approach is obtained by computing the spacecraft motion between successive waypoints using Shooting Methods. The impact of thruster failures is assessed and the cost to recover the nominal path is estimated. Reliability is investigated by adapting the safety metrics of well-known frameworks to the current case study, such as missed-thrust margin. For example, with ballistic propagation after a failure, the minimum distance to the asteroid may be insufficient for mission safety. After adjustment, this metric is maintained above 10 km with minimal impact on the approach sequence and a slightly reduced cost. A modified formulation of the fuel consumption optimization problem is also proposed, including constraints to improve the trajectory robustness. Metrics suitability for optimization is discussed, in terms of computational expenditure and safety performance.