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ROBUST TRAJECTORY OPTIMIZATION FOR AUTONOMOUS ASTEROID RENDEZVOUS

Abstract

In recent years, the exploration of asteroids has been the focus of an increasing number of scientists and engineers. JAXA has achieved sample return missions recently and NASA will complete one sample return mission next year. In addition, NASA, JAXA, ESA and China National Space Agency (CNSA) are planning to send more spacecrafts to asteroids.

Asteroid rendezvous (RDV) is inevitable for asteroid explorations. Due to the large distance from the Earth to asteroids, it takes more than 30 minutes to communicate with the spacecraft. Hence, the spacecraft has to be operated fully autonomously during the RDV. The asteroid RDV phase imposes several constraints such as the approach constraint and attitude constraints, and the onboard guidance system is required to compute in real-time the optimal control input under these constraints. Current RDV guidance systems, however, are not fully-autonomous but rather semi-autonomous due to the complexity of the highly-constrained optimization problems. Therefore, this is less efficient compared to fully-autonomous operations. Hence, new optimization method has to be introduced to achieve real-time fully-autonomous RDV guidance system. In recent years, convex optimization techniques have started to emerge to solve aerospace guidance and control in real-time. The convex optimization guarantees the global optimal solutions unlike other non-convex optimization methods which can have several local optimal solutions, and plenty of studies have shown that the this method is capable of solving the highly-constrained optimization problems and rapidly generating the optimal RDV trajectories.

However, even though the convex optimization technique is applied to the RDV trajectory design, the results are not completely optimal due to the existence of several uncertainties such as target asteroid gravitational field model, the perturbation due to the Solar Radiation Pressure (SRP) and navigation errors caused by the onboard navigation system. The optimization problems with uncertainties is called chance-constrained stochastic optimal control problem. Several techniques have been introduced to solve the problem and they have shown the robustness in the trajectory optimization despite the existence of uncertainties.

In this study, the trajectory optimization algorithm will be developed using the convex optimization. Moreover, the stochastic optimal control will be implemented for the robust trajectory design. The objective of this study is to implement a real-time robust trajectory optimization algorithm for asteroid RDV by combining these two algorithms, and to show the improved performance in comparison to the traditional methods.