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PATH PLANNING AND CONTROL FOR ASTEROID EJECTA COLLECTION AFTER A KINETIC IMPACT

Abstract

In recent years, missions such as JAXA's Hayabusa2 and NASA's OSIRIS-Rex have visited Near Earth Asteroids, explored their environments, and collected samples from these primordial Solar System bodies. Their physical composition is largely unknown and challenging to predict from ground observations. That is why sample collection from such bodies is crucial for the future exploration of the Solar System. Hayabusa2 and OSIRIS-Rex used two different yet similar sampling collection methods. In both cases, a touch-and-go scenario was exploited and, while for OSIRIS-Rex the surface of Bennu was directly sampled, Hayabusa2 first hit asteroid Ryugu with a small kinetic impactor to create a crater. One of the most challenging aspects of such missions is to collect and sample asteroids material by means of an on-ground collection, involving landing (or touchdown) and probing the asteroid's soil. In some cases, the probing may be difficult because of a challenging dynamical environment or dangerous terrain features. In this context, starting from the heritage of the Hayabusa2 mission, we propose a novel mission concept in which the spacecraft hits the asteroid using a small kinetic impactor. Such an small impact will generate a plume of ejecta, similar to the one produced by the impact of the Small Carry-on Impactor (SCI) of Hayabusa2 on asteroid Ryugu. However, differently from Hayabusa2, we envision the possibility of collecting the fragments of the plume directly in orbit; therefore, without landing or touch down. Starting from the dynamical evolution of the fragments, this work studies what are the possible collection regions around the asteroid based on their availability and concentration. To ensure the maximum number of samples is collected, with the desired area-to-mass characteristics, a path planning optimisation is performed to find potential collection trajectories using a problem-specific version of the Ant Colony Optimisation algorithm. The optimisation algorithm considers the cumulative number of collectable fragments, the required delta-v, and mission specific constraints. Finally, we analyse the necessary control history required to follow the optimal trajectory using a Sliding Mode controller. Constraints in terms of illuminations, safety for the spacecraft and communication with the Earth are considered in the trajectory design. The work then discusses the feasibility of the mission and a preliminary concept of operations.