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# OPTIMAL GUIDANCE CONTROL CONSIDERING MULTIPLE CONSTRAINTS FOR ASTEROID SAMPLE RETURN

**Abstract**

The asteroid probe Hayabusa2 successfully touched down on the asteroid Ryugu twice. The samples were collected after the capsule returned to Earth in December 2020, and are currently being analyzed not only in Japan but all over the world. The success of the mission demonstrated the importance of sample return exploration technology for unknown small celestial bodies. The following sample return exploration of unknown small celestial bodies will require a mission that is more advanced than Hayabusa2. From an engineering perspective, it is required to control exploration with higher flexibility. Based on these policies, we started conceptual study. For the future sample return, the spacecraft consists of a main vehicle (cruise stage) that is responsible for the round trip to a target celestial body, and a slave vehicle (exploration landing stage) that conducts observations, landing, and sample collection (touchdown) after arriving at the target.

In this paper, we focus on guidance and control technology related to autonomous rendezvous docking between the main and slave vehicles, formulate a nonlinear optimization problem for guidance control especially when berthing before docking, and examine the feasibility of achieving target accuracy. The results are shown in numerical simulation. The rendezvous docking is structured by dividing its entire sequence into two phases. First, as Phase 1, the direction of radio waves generated by slave vehicle is collected by a phased array receiver installed in main vehicle, and the relative trajectory of main vehicle to slave vehicle is determined. Then, the main vehicle is guided to a distance of several kilometers in the subsolar direction from the slave vehicle. Next, in Phase 2, target marker (TM) light spot mounted on the slave vehicle is captured/tracked by the main vehicle camera, and the slave and the main vehicles are docked using gripping mechanism. Relative six degrees of freedom control is performed until the docking. Phase 2 requires more accurate and fast responsive guidance control, so it is essential to perform autonomous guidance control onboard rather than offline. In this paper, we investigated the optimal guidance control based on multiple constraints such as TM visibility and communication establishment between the main and slave vehicles that exist in the guidance control of Phase 2. Constraints such as TM visibility obtained from the Hayabusa2 flight data were formulated, and a guidance and control law was constructed as a nonlinear optimal control problem while considering them as constraints.