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Author: Mr. Haruhito Ohki
The University of TOKYO, Graduate school, Japan, ohki.haruhito@ac.jaxa.jp

Ms. Kaho Nakagawa
The University of TOKYO, Graduate school, Japan, nakagawa.kaho@ac.jaxa.jp
Prof. Yuichi Tsuda
Japan Aerospace Exploration Agency (JAXA), Japan, tsuda.yuichi@jaxa.jp

PROPOSAL OF TOUCH-AND-GO SAMPLING PROBE USING SOLID ROCKET PROPELLANT AND ITS GUIDANCE AND CONTROL LAW VIA BRAKING-LINE

Abstract

Sample return missions have been carried out as the most sophisticated method of elucidating the universe scientifically and engineeringly. Currently it is getting typical that the main body of the spacecraft itself lands on the target celestial body, but this has been problematic because of the risk of breakdown due to impact by touchdown. The authors envision a new daughter probe that only performs obtaining materials, touch-and-go sampling probe (TAG-SP), which is able to separate the sampling function both physically and systematically. Due to the severe resource constraints of spacecraft, the application of solid rocket propellants (SRMs) with a high thrust to weight ratio is being considered as an ultimately small and simple exploration vehicles. However, guidance and control laws for TAG-SP to autonomously calculate ignition timing and a minimum-time landing trajectory have not been systematized, owing to the infeasibility of handling thrust that cannot be adjusted once ignited and continues to generate thrust nonstop until the end of combustion. Here we propose the braking-line guidance and control law, which defines a guidance trajectory formulated as a linear function of velocity and position and simultaneously interpreted as a sliding surface that defines the ignition timing in the state space, using an algorithm that combines forward and backward propagation. A landing case study on Ceres confirmed that horizontal velocity against the targeted position errors can be absorbed and that a soft landing under vertically 1m/s can be achieved. Furthermore, a Monte Carlo analysis was performed to demonstrate the robustness to initial state errors when detaching from the mother spacecraft, and the landing time was reduced compared to the conventional method. Furthermore, experiments such as a hardware in the loop with using a device equipped with a jet engine simulating SRM at a constant thrust are conducted on a rocket thread running test, and it was confirmed that it is applicable to the actual machine. Our results demonstrate that braking-line guidance and control law is effective in dealing with the thrust constraint of SRM, which is an academic issue unique to TAG-SP. This research is positioned as a study toward the realization of an ultra-small sampling method using SRMs. In the future, we picture a new standard exploration method to provide multiple exploration to multiple celestial bodies, with several TAG-SPs boarded on an orbit transfer vehicle.