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APPLICATION OF THE ONBOARD DOPPLER MEASUREMENT FOR DEEP-SPACE RENDEZVOUS AND DOCKING COMPARED WITH MOVING STEREO-BASED OPTICAL NAVIGATION

Abstract

This research is a study of guidance and navigation in the distant field (10 km 100 m) of deep-space rendezvous and docking. While it is attractive for sample return missions to be able to efficiently collect samples multiple times, there is a risk of losing samples if it is carried out with multiple landings by a single vehicle, as in the case of Hayabusa2. To avoid this risk, a concept is effective where the roles are divided into transference between the earth and an asteroid (handled by a transfer vehicle) and sample collection (handled by a sampling vehicle), and the transfer vehicle (chaser) performs rendezvous and docking towards each sampling vehicle (target) every time for delivery of the samples. Focusing on the distant field of deep-space rendezvous and docking, firstly, the application of the moving stereo-based guidance and navigation can be considered. This method is an optical navigation method which realizes delta-V minimization under high guidance accuracy brought by the stereo vision realized with a monocular camera moving in zig-zag path, and its validity has been proven in the Hayabusa2 mission. The problem here is the uncertainty of the mass of the transfer vehicle. It is because this method calculates delta-V by measuring the thruster injection time, and the uncertainty of the mass affects the uncertainty of delta-V and thus the accuracy of the navigation. On the other hand, as a method to avoid the influence of mass uncertainty, the application of guidance and navigation using Doppler measurement can also be considered. However, considering the communication delay inherent in deep space, 2-way Doppler measurement between the ground station and the transfer vehicle lacks real-time performance, so on-board Doppler measurement, such as 1-way Doppler measurement, which achieves real-time performance by having the transfer vehicle receive accurate and known radio signals from the ground station is preferable. Based on the above, this study investigates a guidance law that can ensure high navigation accuracy even with large mass uncertainty in moving stereo-based guidance and navigation, and also examines the feasibility of a new guidance and navigation method using onboard Doppler measurements, and moreover, considers the pros and cons of both methods. This will demonstrate the usefulness of the new method in the distant field of rendezvous and docking for future sample return missions realized by both the transfer vehicle and the sampling vehicle.