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IMAGE-BASED AUTONOMOUS GUIDANCE, NAVIGATION AND CONTROL OF SPACECRAFT

Abstract

Autonomous GNC (Guidance, Navigation and Control) method using image processing for spacecraft around small bodies is investigated. In case of the asteroid explorer Hayabusa2, launched in 2014 by Japan Aerospace Exploration Agency, GCP-NAV (Ground Control Point Navigation) is utilized. GCP means a feature point such as rock or craters. In another example, OSIRIS-REx, launched in 2016 by National Aeronautics and Space Administration, includes NFT (Natural Feature Tracking). These methods use feature points obtained during neighborhood operation. By matching the feature points with real-time images, spacecrafts can estimate and control their position. GCP-NAV is performed via ground operators, which causes propagation delay. Although NFT is an on-board GNC method, it needs many feature points. When propagation delay is long or neighborhood operation time is short, these are difficult to perform.

The solar power sail mission OKEANOS, planned to be launched in 2026, aims for sample return from a Jovian Trojan asteroid. In this mission, propagation delay is longer than that of Hayabusa2. Moreover, it is difficult to detect sufficient number of feature points because of fuel consumption. Another GNC method is required under the condition.

This paper proposes an image-based on-board GNC method using AIT (Asteroid Image Tracking) and OF (Optical Flow). At high altitude, we use AIT which calculates the centroid of the asteroid captured in the image to estimate the lateral position of the spacecraft. Although Hayabusa2 plans to use AIT, on-board calculation is not taken into consideration. When the spacecraft approaches the asteroid, the images are filled with the asteroid. AIT cannot be used because the centroid can no longer be detected. In such a case, we propose to use OF for navigation. OF is in general used for calculating the amount of

movement, tracking an object, and so on. For example, optical mice take advantage of OF. This method can also be applied to navigation of a spacecraft. By using OF, a spacecraft can estimate not only its lateral velocity relative to the asteroid surface but also vertical position and velocity. In addition, OF does not need feature points databases.

The purpose of this study is to establish an on-board GNC method using AIT, OF. To verify this, numerical simulation is conducted using a 3D model of an asteroid. This allows generating real-time images as computer graphics without observation errors of camera to evaluate the estimation accuracy precisely.