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REAL-TIME SPACECRAFT LOCALIZATION AND MAPPING WITH OPTICAL AND RADIO-BASED ARTIFICIAL MARKERS

Abstract

This paper proposes a real-time navigation method for estimating small-body-relative positions of a spacecraft for a small body exploration. For landing missions on a small body, high-accuracy navigation is important for a pinpoint landing on the small body. Additionally, in the case of exploration to a small body farther than the asteroid main belt, the communication delay with Earth is unacceptably large for feedback guidance via Earth. Therefore, real-time autonomous navigation is required. For these requirements, various navigation methods have been investigated recently. One of the most common methods is position estimation using natural landmarks such as rocks and craters on the surface of a small body. Although, the natural-landmark-based method is not suitable for flat surfaces. On the other hand, the asteroid explorer Hayabusa2 uses the retroreflective marker called the target marker for robust navigation against the surface environments of the small body. The spacecraft can extract the two-dimensional positions of the marker by capturing images with the flashlamp. Although, the detectable range limitations of the retroreflective markers limit the descent trajectories and the landing sites. To accomplish a more flexible and pin-point landing with markers, we assume a new marker system that combines the passive two-dimensional marker extraction with active radio-based two-way ranging between a spacecraft and markers. The radio-based marker seems to limit trajectories fewer than the optical retroreflective marker. Additionally, we propose a navigation method to simultaneously estimate marker positions and a spacecraft position in real-time by combining two-dimensional marker positions and ranging values from the markers spread over a wide area of a small body. The spacecraft position is calculated based on the Bayesian estimation by combining the dynamics-based state transition with the observations of the markers. Furthermore, the marker positions are estimated based on the Bayesian estimation method with the observations. Finally, we evaluate the estimation accuracy and the computational time of the proposed method with the position estimation simulation based on the environment of the Hayabusa2 mission. As a result, we confirm that the proposed method can estimate the positions with high accuracy of several meters in real-time. The authors believe that the proposed navigation method will be a key technology for pin-point and flexible landings on small bodies and further scientific achievements.