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LIDAR-BASED NAVIGATION STRATEGIES FOR A NON-COOPERATIVE TARGET CONSIDERING RENDEZVOUS TRAJECTORY

Abstract

The number of space debris in orbit is increasing every year due to the increase of satellites and collisions with other debris, and active debris removal (ADR) has been attracting more attention. JAXA is promoting the Commercial Removal of Debris Demonstration (CRD2) project, which encourages the development of the on-orbit service market through cooperation with private companies. The CRD2 aims to demonstrate key ADR technologies, such as approach and capture, using the upper stage of the Japanese rocket in low Earth orbit as the target. In ADR missions, the operational sequence such as approaching and capturing debris in the vicinity is one of the most critical operations with the risk of collision, thus relative navigation technology that combines real-time performance, high accuracy, and robustness is essential. In addition, technical issues particular to ADR missions further increase the difficulty of the navigation system. For example, non-cooperative targets such as debris are not equipped with functional equipment like reflectors to assist the navigation system. Therefore, the system must extract physical information about the target, such as its shape and material by itself. It also needs to be robust enough to ensure stable estimation even under the influence of environmental disturbances such as sunlight and earth albedo. With the above background, we are currently studying a matching-based navigation algorithm using LiDAR to acquire navigation techniques for non-cooperative targets. LiDAR has the advantage of being less affected by disturbance light than optical cameras, which are passive sensor. In this paper, we first present our algorithm for estimating the relative 6 degrees of freedom of non-cooperative targets. Next, we describe an operational scenario in the vicinity of debris assuming a real mission like CRD2 and the application of the proposed navigation method. The paper also discusses the issues and specific solutions for LiDAR navigation systems, including configuration constraints such as sensor field of view. Finally, the results of the performance evaluation of the proposed method by real-world tests are described. JAXA has a test facility called SATDyn (Simulation Apparatus for Target capture Dynamics) to verify and evaluate approaching techniques for non-cooperative targets. The SATDyn enables the acquisition of LiDAR point cloud data using a real-scale debris sample model while simulating orbital dynamics. This paper presents the performance validation results based on a Dynamic Open Loop Test (DOLT), which simulates the guidance profile from the fly-around phase to the approach phase.