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SPACE DEBRIS SYMPOSIUM (A6)
Space Debris Removal Technologies (5)

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LIDAR-BASED AUTONOMOUS POSE DETERMINATION FOR A LARGE SPACE DEBRIS

Abstract

Many recent studies on the stability of the debris population in low Earth orbit (LEO) have shown that the environment has reached a point where collisions among orbiting objects will force LEO population to increase even without new launches. Recent NASA results have demonstrated the need for the active removal of at least five large objects per year to prevent the triggering of the "Kessler syndrome". Active Debris Removal (ADR) missions pose many significant technological challenges, starting from the rendezvous with an uncooperative target, which is not arranged to be approached by a removal system. In this respect, a major task is to develop reliable and robust techniques for autonomous determination of the target pose. Existing pose determination techniques can be classified in monocular and 3D techniques. In this last case, a 3D model of the target is stored or built on board to compute the pose by comparing global or local features of the target to the same features in the model. This is the reason way they are generally referred to as model based techniques, which are of high interest when the target is uncooperative, even if their use in space present many technical concerns that need extensive investigations. The aim of this paper is to investigate the performance of a LIDAR-based system for pose determination of a known large debris. This work is conducted within a feasibility study for an ADR demonstration mission. LIDARs can provide reliable and accurate pose estimates thanks to their high robustness to variable illumination conditions and the capability to discriminate the target from the background. In contrast, challenging issues are relevant to real-time operation and robustness of the pose solution. LIDAR measurements consist of a 3D-point cloud, which is used for pose acquisition and tracking. For pose acquisition, an optimized 3D Template Matching technique is introduced, specifically thought for on-board autonomous operations. For pose tracking, different variants of the Iterative Closest Point (ICP) algorithm are investigated. Specifically, two approaches, namely nearest neighbor and normal shooting, are compared to identify the best trade-off between accuracy and computational resources. To this end, a simulator is developed implementing realistic debris geometry and motion, debris/removal system relative dynamics, sensor operation and pose estimation algorithms. Results are used to evaluate the achievable pose estimation accuracy and the impact of LIDAR parameters, as angular resolution and FoV, debris characteristics, as size and configuration, and debris/removal system relative dynamics.