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RELATIVE NAVIGATION STATE ESTIMATION PERFORMANCE FOR ORBIT DEBRIS REMOVAL AND DEEP-SPACE RENDEZVOUS

Abstract

Mission concepts which actively pursue large derelict spacecraft or rocket bodies were put forward by many organisations in the past in order to mitigate the increase in the amount of space debris. In some concepts, a chaser spacecraft reaches the debris spacecraft, synchronises its attitude motion with it, grapples it and takes it down at a lower altitude, where de-orbiting and re-entry is guaranteed to occur. In order to perform the proximity operations, the chaser spacecraft requires an accurate knowledge of the target spacecraft states. Relative navigation – the determination of relative position and attitude states – has been clearly identified as a key critical technology for such missions.

Many of the solutions put forward involve the combination of active and passive sensors to measure the absolute states of the chaser and the relative pose of the debris. An example of such sensor suite is the combination of a scanning Lidar sensor (providing range, bearing and relative orientation measurements at short range), an infrared camera (providing bearing estimates at long range), an IMU, a star tracker and a GPS (to support state estimation of the chaser spacecraft).

However, these sensor measurements do not directly provide information regarding the complete relative state vector. Moreover, measurement availability evolves over the duration of the capture scenario. A state estimation software function is required to fuse the information from sensor inputs and ground tracking and estimate the complete state vector, including relative position, velocity, attitude and angular rate, over the complete operational sequence.

An Extended-Kalman-Filter-based solution is thus proposed to meet these objectives. The solution has been designed and implemented in a high-fidelity end-to-end simulation environment in order to estimate the state estimation performance of the integrated hardware/software system in a realistic Low-Earth Orbit debris removal scenario. Monte-Carlo simulations have been executed in order to verify state estimation accuracy and robustness under realistic system and environmental uncertainties.

The paper shall provide an overview of the reference mission scenario, the state estimation system architectural design and the expected achievable performance for the reference design scenario. The paper

shall demonstrate that such an integrated system is not only applicable to rendezvous with an uncooperative target, but also to future deep-space docking and rendezvous missions. Performance estimates will also be provided for a deep-space rendezvous mission at the Earth/Moon L2 point with a future manned space station.