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CASCADE ARCHITECTURE FOR ONBOARD ESTIMATION OF AN UNKNOWN, UNCOOPERATIVE SPACE DEBRIS.

Abstract

Robotic Active Debris Removal relies on the precise characterization of relative state debris for further motion-planning, safe grasping and disposal. When dealing with a known target, a simplified 3D model of the target can be used onboard the chaser to retrieve the relative pose (relative position and attitude) from sensing data using specific 3D to 3D or 2D to 3D alignment algorithms. With unknown targets however, such strategies become impossible. Therefore, the motion model and the shape of the target therefore have to be simultaneously estimated in order to select a grasping point and safely approach it. Such an estimation can be performed on ground by taking advantage of the computing power available and processing all measurements at once through a graph representation. On-board estimation, however, cannot rely on extended computing power, ruling out the ability to solve an entire, complex graph.

In this paper, we propose a novel cascade architecture using sensing from a depth sensor (LiDAR) and a monocular camera which, once combined with Attitude Control System data from the spacecraft, enable reconstruction of a 3D point cloud of the target as well as its attitude and inertia properties. First, an error-state Extended Kalman Filter operating on the SE(3) group constructs a map of the target as well as the rough relative motion of the chaser with regards to the target, using detected points of interest in the camera image and fusing depth data. Once enough knowledge is gathered, either by loop-closing, covariance threshold or designed time-out, the newly estimated relative angular speeds are combined with the inertial ones coming out of the chaser's ACS system, enabling a second algorithm to solve a simple graph to determine the principal axis of inertia as well as inertia parameters of the target. Finally, another error-state Extended Kalman Filter refine the estimation still using sensing data but also taking advantage, this time, of the chaser-target relative motion as well as the newly estimated attitude and inertia parameters. This cascade technique allows tackling unknown, uncooperative spacecrafts without any prior knowledge except its rough orbital elements from the Space Debris Catalogue. We present simulation results that show a mean squared reconstruction error below 0.1m as well as a mean squared attitude error below 0.5 degrees.