LIDAR-based pose estimation for non-cooperative rendezvous

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Abstract- The interest in orbital non-cooperative rendezvous is growing as it could allow satellite servicing or space debris deorbitation. In this paper, a navigation solution is presented for non-cooperative rendezvous using scanning LIDAR measurements at close range. The complete 6-DOF relative state is estimated with ICP algorithm in closed-loop with a Kalman filter.

The model-based ICP algorithm matches two sets of geometric model and measured points to calculate relative attitude and position. This information is the input of a Kalman filter, using free-rotating object equations for attitude estimation and Tschauner-Hempel equations for position estimation.

A rendezvous simulator was developed to implement this navigation solution and simulation results are presented for a debris representative of H10 Ariane 4 upper stage. This target is cylinder shaped and presents symmetry around roll axis, making the attitude estimation particularly challenging. Simulations are run using a sensor model and give results in terms of relative position and attitude errors for rendezvous with a space debris. Different relative trajectories are tested for distances between 100m and 20m (station-keeping, linear approach, fly-around). The interest of adding extended Kalman filter to ICP algorithm is investigated showing promising results while compatible with real time constraints. The specific 6DOF initialization issue whether from absolute navigation or 3DOF relative navigation (either with an optional camera or the LIDAR itself) is addressed in order to propose a full navigation architecture solution based on sensors suite composed of star-tracker, gyrometers, accelerometers, LIDAR and an optional camera. The precision obtained is compared to corridor approach constraints derived from space station docking or debris removal missions.