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SAFE OPERATIONS IN PROXIMITY OF SPACE DEBRIS: RELATIVE MOTION DESIGN AND POSE ESTIMATION

Abstract

Large space debris, like non-functional satellites or abandoned rocket bodies, represent a major threat for the operation of satellites, especially in the most crowded orbital regions, such as low Earth orbits and geostationary orbits. Moreover, onboard explosions caused by degradation of electric equipment or collision with other debris or operative spacecraft may cause an uncontrolled increase in the debris population, thus having a catastrophic effect on the feasibility of future space missions. In this framework, the concept of active debris removal has been introduced. Among the related technical challenges, this work investigates the problem of an active spacecraft (chaser) orbiting in close-proximity to these large objects (targets), for instance, for monitoring purposes. In this scenario, the collision risk can be significantly limited by designing safe relative trajectories as well as by providing robust and accurate relative navigation solutions. With regards to the first point, a semi-analytical method to compute differences between target/chaser mean orbit parameters which define desired relative trajectories is applied. Major advantage of this method is that it allows freely selecting size, shape and orientation of the relative trajectory. It is used to design trajectories which never intersect the target along-track direction, thus almost cancelling out the risk of collision due to unintentional along-track drift of the relative motion, which is important to relax control requirements (hence, the well-known concept of passive safety is satisfied). Concerning relative navigation, the capability to accurately estimate the relative position and attitude (pose) between the two space objects is of utmost importance. A robust LIDAR-based architecture including autonomous failure detection strategies is exploited to this aim. The algorithms composing this architecture do not require fiducial markers on the target but only the knowledge of a simplified target model. The close relation between these two problems is given by the fact that the proposed design approach can be used to generate trajectories which provide favorable observation conditions for pose estimation. This latter point is demonstrated with numerical simulations in which the operation of an active LIDAR, and the relative dynamics are realistically reproduced. Preliminary results show that pose estimation accuracy can be improved if the time interval in which the target global structure is in the LIDAR field of view without self-occlusion is maximized. To this aim, it is important to take absolute rotational dynamics of the target and its geometry into account.