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ON ORBIT SERVICING GNC THROUGH A DUAL QUATERNION APPROACH

Abstract

On Orbit Servicing (OOS) is an ever-growing topic in the space sector. OOS mission concepts may include refueling, orbital inspection, orbit insertion, subsystem repair or substitution, bus augmentation and even planned decommissioning. In order to propose an appealing product, OOS providers will need to have a strong business plan and high quality of services. The latter is achieved through reliable and robust in-orbit operations relying on a dedicated guidance, navigation and control (GNC) system as well as on a proper robotics system to achieve the desired tasks. Relative position and attitude GNC is the first element to be addressed. In this article a dual quaternion (DQ) parametrization will be used to derive a robust GNC system capable of achieving desired performances under uncertainties and complex non-linear effects. These performances are derived through analysis on the new provider to customer perspective. The ability to cope with non-foreseeable customer satellite parameter changes (ex: non correctly deployed solar panels) as well as servicer satellite center of mass changes (robotic arm movement, sloshing, fuel transfer, etc.) is required to ensure the safety of operations. Special focus will be given to the benefits given by the DQ formulation as well as the known problematics of unwinding and higher dimensionality. The use of DQ allows to easily determine data fusion schemes as well as solving relative pose estimation problems arising from the use of sensors like cameras and LIDARs. The approach is general and can be applied to several other cases where relative position and attitude control is necessary. In fact, the acquired GNC strategy will be also applied to robotic arm guidance and control, evaluating the scalability and flexibility of the approach. Base-to-end-effector data fusion will be addressed to empower task scheduling, collision avoidance target recognition and other functions. Task planning optimization with DQ is included to generate a relative end effector trajectory that is able to be adapted to change in customer to servicer relative displacement. A simulation campaign, using a custom developed multibody space simulator, is performed to verify requirements satisfaction and to evaluate the nominal performances of the proposed GNC system. As final deliverable, important insights on the OOS GNC problem are derived in order to prepare technical guidelines for future OOS missions.