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SOFT AND ENERGY-EFFICIENT ROBOTIC CAPTURE OF TUMBLING SPACECRAFTS

Abstract

The autonomous capture of non-cooperative objects with unknown dynamic parameters is a priority task for near future space activities. This key technology can be used in several space robotic missions such as in refuelling, repairing, servicing satellites, or for the removal of space debris. In the capturing operation, an accurate robot trajectory control should be used in order to minimize the impact force at the time of capture, and the robotic system should dampen the spin motion of the target in the post-capture phase. Indeed, the impact force could damage either the manipulator or the target, cause an undesired spacecraft attitude destabilization, or cause the target to be pushed away. Therefore, the robot trajectory has to be computed in such a way that the relative velocity between the robot end-effector and the target at the time of capture is very small. Moreover, the spacecraft attitude deviation should be minimized during and after the capture in order to maintain the communication link with the ground station. In this operative scenario there are several unsolved issues, mainly concerning the accurate identification of the dynamic parameters of the target, and the design and implementation of effective systems for impact reduction and motion damping of the target satellite in the post-capture scenario. In this paper, a novel control method which carries out the motion damping of the spinning target in the post-capture phase in an energy-efficient way is presented, thus enhancing the system useful life. The control method is also able to identify the main inertial parameters of the target satellite during the post-capture motion. Moreover, a new mechatronic system to dampen and reduce the effects of the impact between the robotic arm and the target satellite is developed, using compliant joints and backlash which can be activated/deactivated during the impact. Both the aforementioned systems are tested and demonstrated by means of dynamic simulations for evaluating their performance. Several test cases with different spin of the target are considered in order to simulate real space robotic operations scenarios. Finally, a real prototype has been developed and tested in laboratory in a simulated microgravity test facility in order to experimentally validate the proposed concepts.