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COMBINED CONTROL AND NAVIGATION APPROACH TO THE ROBOTIC CAPTURE OF SPACE VEHICLES

Abstract

The potentialities of In-Orbit Servicing (IOS) to extend the operational life of satellites and the need to implement Active Debris Removal (ADR) to effectively tackle the space debris problem are well known among the space community. Research on technical solutions to enable this class of missions is thriving, also pushed by the development of new generation sensors and control systems. Several solutions have been proposed over the years to safely capture orbital objects, the majority relying on robotic systems. Among private companies, space agencies and universities, the European Space Agency (ESA) has been developing technologies in this field for decades. A promising solution is the employment of an autonomous spacecraft (chaser) equipped with a highly dexterous robotic arm able to perform the berthing with a resident space object. This operation poses complex technical challenges both during the approach phase and after contact. In this respect, the design of an effective, reliable, and robust Guidance Navigation and Control (GNC) system, for which several algorithmic architectures and hardware configurations are possible, plays a key role to ensure safe mission execution.

This work presents the outcomes of a research activity performed by a consortium of universities under contract with ESA with the goal to develop the navigation and control sub-systems of a GNC system for controlling a chaser equipped with a redundant manipulator. Both the final approach until capture and the target stabilization phase after capture are considered in the study. The proposed solution aims at the implementation of a combined control strategy. Robust control methods are adopted to design control laws for the uncertain, nonlinear dynamics of the chaser and of the complete chaser-target stack after capture. Visual-based solutions, i.e. relying on active/passive electro-optical sensors, are selected for relative navigation. A complete sensor suite for relative and absolute navigation is part of the GNC system, including transducers for robot joint measurements. To properly validate the proposed solutions, a complete numerical simulator has been developed. This software tool allows to thoroughly assess the system performance, accounting for all the relevant external disturbances and error sources. A realistic synthetic image generator is also used for relative navigation performance assessment. This paper presents the design solutions and the results of preliminary numerical testing, considering three mission scenarios to prove the flexibility of the solution and its applicability to a wide range of operational cases.