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MACHINE LEARNING APPLIED TO AUTONOMOUS ROBOTIC CAPTURE OF AN UNCOOPERATIVE TUMBLING TARGET

Abstract

Recent studies indicate active debris removal (ADR) as the only viable way of reducing the space debris population and preserving the space environment for future generations. Upper stages appear to be among the most suitable targets, given their number, mass properties and spatial distribution. Among the proposed ADR technologies, those involving orbital robotics are the most mature ones, but until now, they have never been used without humans in the loop. Autonomy is particularly required in the capture phase of an ADR mission, given the predicted limited reaction time.

To support this kind of missions, the following paper presents a possible method for autonomous capture and stabilization of a tumbling, uncooperative upper stage, by means of a robotic spacecraft, using machine learning. The method uses dynamical coupling between the manipulator and its base spacecraft to optimize its entire configuration, in the pre-capture phase, and limit the transmitted angular momentum, in the post-capture phase.

The proposed method is a two step process performed in sequence. At first, a workspace analysis and reachability optimization are performed off-line (and on ground), using machine learning. Then, the results from the previous step are used as an initial guess for the real-time trajectory generation and control not just of the manipulator but also of the attitude of the base. The reason for this division lies in the computational requirements of the learning algorithms, that can not be performed on-board within a reasonable time.

Two methods are identified for the off-line calculation: a) a black box approach and b) parametrization. In the first one, the learning algorithm selects and evolves on its own the most suitable outputs, starting from current states of the chaser and target. The second approach relies instead on the external selection of the outputs to be optimized and their parametrization.

The mathematical formulation of the optimization problem is also presented in the paper along with applicability analysis of the defined approaches for the off-line calculation.

In conclusion, the presented method appears promising given its ability to autonomously provide optimal configuration of the entire spacecraft, while taking into account the feasibility of the trajectory, limited time frame, dynamic coupling and limited on-board resources.

In the end, steps for further development and implementation of the presented method are discussed and areas for improvement are identified.