# Towards Sequential Controller Composition for Robotic Active Debris Removal

Shubham Vyas[1 [0000−0001−8773−8435]], Shivesh Kumar[1 [0000−0002−6254−3882]], Lasse Maywald[1 [0000−0002−4381−2880]], and Marko Jankovic[1 [0000−0002−9904−7241]]

Robotics Innovation Center, German Research Center for Artificial Intelligence (DFKI GmbH), 28359 Bremen, Germany
{firstname,lastname}@dfki.de

**Abstract.** Robotics Active Debris Removal (ADR) is one of the potential methods for reducing space debris. A robotic ADR mission generally comprises the following phases: Approach, Capture, and Detumble. Current literature focuses on trajectory planning and control during these individual phases with scarce work on multi-phase control. However, for a feasible mission, a method to fuse the various single-phase controllers is required to ensure a smooth transition between the phases during operation. This method should guarantee stability through phase/controller transitions to perform a successful ADR operation using a robotic manipulator. In this presentation, we discuss using sequential controller composition as a potential method for achieving stability through phases/controllers. The concept of sequential composition of controllers to guarantee stability through controller transitions has been previously used in the control of underactuated systems such as legged robots and perching gliders. The central idea lies in the construction of an approach controller whose goal lies within the region of attraction of the capture controller, whose goal, in turn, lies within the region of attraction of the detumble controller. Such controller design can potentially guarantee the stability of the ADR operation through the approach, capture, and detumble phases along with the attainment of the goal. To synthesize such controllers, the analysis of controllers for each of the phases must be performed and their regions of attractions computed. In this work, we present an optimal post-capture detumbling along with a method for its region of attraction analysis. We then propagate this region of attraction by projecting it through the bilateral contact dynamics constraints experienced during the capture phase. This allows to potentially connect the detumble and contact controllers using their regions of attraction thus demonstrating the initial aspects of controller composition for robotic active debris removal. Furthermore, the capture's contact region of attraction can be used by the final-approach controller as the goal region. The sequential controller composition for a robotic ADR mission is demonstrated using simulation.

**Keywords:** Space Robotics · Robotics · Controller Composition · Active Debris Removal.