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MODEL PREDICTIVE IMPEDANCE CONTROL FOR ORBITAL REPLACEMENT UNIT INSTALLATION BY A CUBESAT SERVICER

Abstract

On-Orbit Servicing (OOS) has been the subject of research for decades as the community has recognized the potential of repairing, refuelling, upgrading, and otherwise maintaining space assets. Research into OOS has covered a wide array of servicer spacecraft designs and simulations of servicing tasks. Despite the large body of work, only a handful of demonstration missions and a single commercial mission have been flown to date. Part of the hesitation surrounding OOS is the economic cost associated with designing and building servicer spacecraft. To address this concern, in this paper we are presenting a CubeSat system for a specific OOS mission.

CubeSats have been proven as a cost-effective platform with a significantly lower economic barrier relative to larger spacecraft. The reduced cost could help to make OOS a viable venture, with CubeSats already demonstrated to be capable of debris removal and orbital assembly tasks. The capabilities of CubeSats as servicers, however, have yet to be explored. In this paper we present the results of a simulated 6U CubeSat servicer equipped with a robotic arm performing the installation of a small Orbital Replacement Unit (ORU) with 4 conical guide-pegs, on a target satellite.

The simulation contains a free-flying CubeSat servicer, with its position and orientation controlled by thrusters and reaction wheels, respectively. The CubeSat's robotic arm has 1 degree of freedom (DoF) actuated by a prismatic joint with a maximum reach of 300 mm. This system design eliminates the complexities of multi-DoF robotic manipulators and presents a predictable disturbance to the CubeSat spacecraft. Furthermore, in considering a real-world application of this servicer, a reduction in the number of joints in the robotic manipulator corresponds to a reduction in the number of failure points for the servicer.

Control of the proposed servicer system is accomplished through the use of Model Predictive Impedance Control (MPIC) — an extension of Model Predictive Control (MPC). MPIC allows for robotic systems to incorporate the compliant behaviour generated by impedance controllers into MPC, which in turn allows for actuator constraints to be considered in determining control values. To demonstrate the performance of the controller and to highlight its robustness, several scenarios are simulated starting with perfect alignment between the ORU and its installation port, and initial conditions in which the axial position and orientation are misaligned. The results confirm the feasibility of using the proposed servicer to complete an ORU installation task.