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CONTROL SYSTEM FOR A TORQUE-SENSITIVE SPACE ROBOTIC ARM

Abstract

Future space missions will require sensitive robots to perform interaction-rich manipulation tasks to enable In-Space Servicing, Assembly and Manufacturing (ISAM) activities. While impedance-controlled robots are widely used on Earth to conduct such tasks, they have not yet been applied in space. Operating a robot in such remote environment creates a set of unique challenges for its control system which we solve with a unique Virtual Fixtures approach, where a set of semi-automated fixtures allow for both human teleoperation with force feedback as well as for fully autonomous execution.

This paper introduces the control approach which has been implemented for the SpaceDREAM mission, aiming to validate an impedance-controlled robotic arm in Lower Earth Orbit (LEO) conducted by the German Aerospace Center (DLR) in cooperation with KINETIK Space GmbH and the Technical University of Munich. While the mission is still waiting for a launch opportunity, the system has already been tested on a parabolic flight during the RoboGrav project which provided invaluable measurements which will also be presented in this work.

The robotic system consists of four torque controlled joints based on the light weight robot technology developed at DLR. This design allows for a full control of the position, leaving one degree of freedom left in the robot's nullspace. A pin end effector allows interactions with the environment, e.g. a spring assembly and a Launch Adapter Ring (LAR) are mounted to the robot's base to demonstrate interactions. On joint level, high rate torque, impedance and position control loops are implemented with controllers that can be parameterized externally. Using the joint torque interface, first, torques compensating the gravity influence on Earth are applied to the robot's joints ensuring similar behavior both under gravity as well as under 0g conditions. With this compensated robot, the control software described in this work implements high-level joint impedance and Cartesian impedance controllers. The Cartesian impedance controllers are based on a probabilistic adaptive Virtual Fixtures formulation, where an optional automation capability allows for an autonomous execution while interaction through a human user is still possible at every moment.

Central for transferring of the approach to a space robot is the implementation of the controllers on a space-grade On Board Computer (OBC) with limited resources. In the remainder of the paper, we will outline the controller implementation under those resource limits and specifics of the robot and discuss potential improvements using measurements from the parabolic flight experiments.