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MODELLING AND COMBINED CONTROL OF A SATELLITE WITH A ROBOT ARM FOR ACTIVE DEBRIS REMOVAL

Abstract

An overview of recent results on the topic of modelling and Combined Control for a chaser satellite with a robot arm is presented for an Active Debris Removal (ADR) scenario. The results were obtained during ongoing and past projects between DLR and ESA as well as DLR internal studies.

Combined Control is defined as a single controller which handles all degrees of freedom (DOF) of a satellite platform and its robot arm system. Therefore, it coordinates all sensor data and actuation to obtain the desired motion of the satellite and the robot arm.

Nonlinear simulation models for an ADR scenario for the inactive ENVISAT target satellite have been developed. The nonlinear simulation tool, based on the object-oriented modeling language Modelica, includes the satellites, the robot arm and relevant disturbance terms such as sloshing and thruster dynamics, sensor noise, a visual camera performance model, flexible dynamics and the Low Earth Orbit (LEO) environment.

The Combined Controller is designed using a multi-stage and multi-objective design and optimization procedure which includes classical robust control design and linear analysis techniques, as well as nonlinear simulations using multiple scenarios (cases). Different controller architectures were analyzed, including robust MIMO control and nonlinear feed-forward control combined with linear feed-back control.

Challenging aspects for the design are low sampling rates of the onboard sensors and thruster commands, limited robot actuator and thruster capabilities as well as uncertain parameters and sensor noise, which are considered in the design procedure.

In addition, advanced trajectory planning algorithms for the approach, capture and escape mode were developed, which consider the highly over-actuated system of a seven axis robot arm and the 6 DOF satellite motion as well as the actuator limitations.

The Combined Control approach was designed and verified using the nonlinear simulation tool for different control modes of the ADR scenario. It allows using all DOF of the system simultaneously. Therefore, highly dynamic maneuvers of the robot arm and satellite are possible. The coordinated motion allows for a synchronized approach and grasping of the rotating target and safer escape of the robot arm and chaser satellite in the case of unforeseen events.

The simulation results show promising results, which will be further investigated in planned Hardware in the Loop (HiL) experiments on robotic simulators.