Paper ID: 90403
oral
student

IAF SPACE SYSTEMS SYMPOSIUM (D1)
Cooperative Systems (4)

Author: Mr. Lorenzo Capra
Politecnico di Milano, Italy

Mr. Matteo D'Ambrosio
Politecnico di Milano, Italy
Prof. Michèle Lavagna
Politecnico di Milano, Italy

LEARNING-BASED TRAJECTORY OPTIMIZATION OF A SPACE MANIPULATOR POST TARGET-GRASPING

Abstract

The application of space manipulators for In Orbit Servicing (IOS) represents a paramount pursuit for leading space agencies, given the substantial threat posed by space debris to operational satellites and forthcoming space endeavours. A pivotal prerequisite for harnessing the potential of space servicing capabilities lies in the ability to repurpose space assets beyond their anticipated operational lifespan. Within this context, space robotics and heightened autonomy emerge as indispensable catalysts, unlocking a wealth of possibilities. The paper discusses innovative guidance and control strategies for the path-planning of a spacecraft equipped with a 7-dof robotic arm, in the peculiar case of post target-grasping. An uncooperative target of unknown inertial properties is captured by the space manipulator system and the overall stack dynamics is analysed. The trajectory of the resulting multi-body system is optimized with the goal of reaching a specified set pose, while maximizing a designed objective function and satisfying certain constraints. A learning-based approach is selected, due to its adaptivity to uncertainty in the surrounding environment and complex dynamics. Reinforcement Learning methods are here preferred thanks to the generalizing learning capabilities of these AI approaches, that are specifically exploited to gain flexibility and robustness in robotic guidance and control policies. These techniques emerge as a viable solution for effective decision-making, especially in problems where future dynamical states and uncertainty must be considered. The problem at hand focus on the post-grasping scenario of an IOS mission, in which an unknown target is captured by the space manipulator and the overall system needs to reconfigure according to a specified desired pose. By training the RL-based agent on simulation environment, the decision making is optimized to maximize the objective function. This function is designed considering the desired pose, via an Artificial Potential Field, and then augmented with two other signals: the first has the intent of promoting collision avoidance between the elements of the multi-body system, the second related to the robotic arm singularity, which is evaluated via singular value decomposition of the Generalized Jacobian Matrix. The resulting learning-based agent undergoes an extensive Montecarlo analysis to assess the effect of several randomized parameters; mainly the unknown properties of the target are randomized and varied across the simulations to evaluate the generalizing capabilities of the RL decision-making policy. The findings of this research highlight the applicability of RL in advancing the capabilities of space robotics for In Orbit Servicing.