69th International Astronautical Congress 2018

Paper ID: 45776
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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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OPTIMAL IN-ORBIT OPERATIONS OF A MULTI-DEGREE OF FREEDOM SPACE MANIPULATOR

Abstract

Space manipulators are complex systems made of a platform equipped with one or more deployable robotic arms. They will be playing a major role in future autonomous on-orbit missions such as building large space structures and servicing satellites which ran out of propellant or need repair. In the latter case, the robotic arm mounted on the floating base must be deployed to reach the target spacecraft. In this work a multibody approach is adopted to describe the full three-dimensional non-linear dynamics of a space manipulator. The latter presents a seven-degree of freedom arm. More specifically, it is formed by seven links: the first six are connected by means of revolute joints (with each rotation axis oriented at 90° with respect to the previous one) and the last two using a prismatic joint. A rotational motor is present at each revolute joint, while a translational actuator is placed along the prismatic joint axis. The present paper aims at studying optimal trajectories for the arm deployment and developing a suitable control strategy to achieve the mission goal. The multi-objective optimality criterion is based on the minimum time necessary to complete the maneuver, the minimum power consumption and the minimum disturbance on the manipulator base position and attitude which are certainly features of relevance in space applications. In addition, the final point for the end-effector position is considered to be moving due to the fact that the target satellite is assumed to be non-cooperative and tumbling which are the worst conditions to be managed by an autonomous robotic manipulator. The optimization will also take the presence of obstacles between the end-effector and the target point into account as well. The influence of non-modeled dynamics such as solar panels structural flexibility and joints elasticity on control effectiveness will be analyzed as well. Furthermore, the possibility of faults concerning one or more motors actuating the arm (and the resulting reduction in the number of degrees of freedom) is included in the control logic structure. The deployment maneuver is studied by means of a co-simulation involving a multibody code (for describing the dynamics of the space robot) together with Simulink (for the determination of the control actions). The co-simulation has proved itself being a particularly useful tool to implement robust control applied to detailed dynamic systems giving accurate information about the system dynamics while choosing the complexity level of the model used for the control synthesis.