MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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3D MINIMUM REACTION CONTROL FOR SPACE MANIPULATORS

Abstract

The ongoing studies on debris removal strategies and on-orbit operations often call for the use of space manipulators, in order to grasp and handle specific targets (e.g. uncooperative spacecraft). One of the main issues of the operations concerning the use of space manipulators is the interaction of the arm motion with the attitude control of the spacecraft platform. In many cases, the control strategy is to switch the spacecraft attitude control off during the arm deployment, in order to avoid an unstable feedback behavior. As a consequence, very low reaction forces and momenta exchanged between the arm and its base are highly desired. Even if a control attitude is used, the reduction of the reactions at the base would decrease the control cost during the operations.

A solution to this problem is the so-called 'reaction null space' technique, that has been largely investigated in the past years. Its advantage is that the manipulator is moved in such a way that the condition of null reactions at the base is exactly satisfied at every time. The drawback is that the manipulator's workspace is drastically reduced.

In order to tackle this problem, the constraint of null reaction must be relaxed, and a limited amount of reactions must be accepted, compatibly with the mission requirements. Most of the current research addresses this problem proposing different approaches but limiting to the two-dimensional case. However, it is fundamental to deal with the complexity involved in three dimensional cases in order to move to more practical and realistic cases.

Following this motivation, this paper investigates the highly non-linear 3D dynamics of multibody space systems in order to design a control method for space manipulators which minimizes the dynamic coupling with the spacecraft' structure to which it is anchored. The equations of motion of a fully three-dimensional multibody system are derived; then, a minimum reaction control problem is formulated and applied to a typical mission scenario involving the robotic arm deployment for on-orbit servicing. Finally, a sensitivity study on the inertial systems parameters is provided to verify the robustness of the proposed control method.