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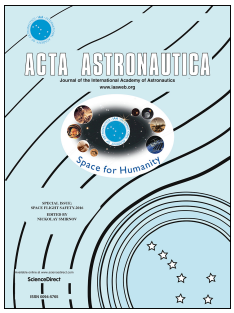

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Coordinated control of a space manipulator tested by means of an air bearing free floating platform

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Abstract

A typical approach studied for the guidance of next generation space manipulators (satellites with robotic arms aimed at autonomously performing on-orbit operations) is to decouple the platform and the arm maneuvers, which are supposed to happen sequentially, mainly because of safety concerns. This control is implemented in this work as a two-stage Sequential control, where a first stage calls for the motion of the platform and the second stage calls for the motion of the manipulator. A second novel strategy is proposed, considering the platform and the manipulator as a single multibody system subject to a Coordinated control, with the goal of approaching and grasping a target spacecraft. At the scope, a region that the end effector can reach by means of the arm motion with limited reactions on the platform is identified (the so called Reaction Null workspace). The Coordinated control algorithm performs a gain modulation (finalized to a balanced contribution of the platform and arm motion) as a function of the target position within this Reaction Null map. The result is a coordinated maneuver in which the end effector moves thanks to the platform motion, predominant in a first phase, and to the arm motion, predominant when the Reaction-Null workspace is reached. In this way the collision avoidance and attitude over-control issues are automatically considered, without the need of splitting the mission in independent (and overall sub-optimal) segments.

The guidance and control algorithms are first simulated by means of a multibody code, and successively tested in the lab by means of a free floating platform equipped with a robotic arm, moving frictionless on a flat granite table thanks to air bearings and on-off thrusters; the results will be discussed in terms of optimality of the fuel consumption and final accuracy.

Keywords: Space manipulators; Jacobian control; Reaction null control; Coordinated control; Space debris; On-orbit servicing.

1. Introduction

Space manipulators are the subject of extensive research activities in recent years (ref. [1], [2], [3]). In fact, they must be considered an important asset for the achievement of the ambitious goals of near future space missions. Debris removal ([4], [5]) and on-orbit servicing are activities that require the capability of handling floating objects by means of a floating chaser platform. The characteristic unconstrained space environment is the main reason that pushes researchers in looking for dedicated solutions in terms of guidance, navigation and control of these manipulators with respect to their well-established terrestrial counterparts.

A movement of the manipulator in a free floating scenario causes a disturbance on the chaser's platform. It is true that this effect is nearly negligible when the platform is much larger than the manipulator in terms of inertia moments and mass (see the Canadarm and Canadarm2 well-known cases), yet in future missions it is very likely that the platform's and the manipulator's properties will be of the same order of magnitude. Additionally, the operations will be autonomous and not remotely controlled. Therefore specific strategies should be taken into account according to the different phases of the manipulator operations.

Usually, the control of the platform (attitude and translation) is disabled during the mission phases that involves the deployment of the robotic arm and the contact and capture of the target (this is sometimes called a *free-floating* configuration [6]). In order to cancel the disturbance that is caused by the movement of the manipulator, Reaction Null (RN) strategies [7], [8] have been developed in the past. According to such control algorithms, the angular accelerations of the platform can be decoupled by the accelerations of the arm's joints, provided that specific paths are followed. This strategy has the drawback to greatly reduce the workspace of the manipulator, meaning that not all the