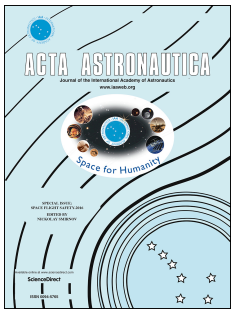
Accepted Manuscript



Vibration suppression control of free-floating space robots with flexible appendages for autonomous target capturing

Deshan Meng, Weining Lu, Wenfu Xu, Yu She, Xueqian Wang, Bin Liang, Bo Yuan

PII: S0094-5765(17)31858-1

DOI: 10.1016/j.actaastro.2018.07.044

Reference: AA 7025

To appear in: *Acta Astronautica*

Received Date: 18 December 2017

Revised Date: 14 July 2018

Accepted Date: 22 July 2018

Please cite this article as: D. Meng, W. Lu, W. Xu, Y. She, X. Wang, B. Liang, B. Yuan, Vibration suppression control of free-floating space robots with flexible appendages for autonomous target capturing, *Acta Astronautica* (2018), doi: 10.1016/j.actaastro.2018.07.044.

Vibration suppression control of free-floating space robots with flexible appendages for autonomous target capturing

Deshan Meng[a,b], Weining Lu[a], Wenfu Xu[c] , Yu She[b], Xueqian Wang[a*], Bin Liang[a*], Bo Yuan[a]

[a]*Shenzhen Key Lab of Space Robotic Technology and Telescience, Graduate School at Shenzhen, Tsinghua University, Shenzhen, China*

[b]*Department of Mechanical and Aerospace Engineering, The Ohio State University, Columbus, USA*

[c]*Shenzhen Graduate School, Harbin Institute of Technology, Shenzhen, China*

Abstract

Some flexible appendages, such as solar panels, communication antenna and other large structures are mounted on the base of the space robot. The structure flexibilities will cause vibration during the operation of manipulators. Due to complicated dynamic coupling among manipulators, the rigid base and flexible appendages, it is very challenging to control the end-effector to track inertial trajectories, especially when the target states are constantly changing. This paper proposes a vibration suppression method for autonomous target capturing during the preimpact phase without controlling the base. Firstly, we derive the rigid-flexible coupling dynamics of a space robot system with flexible appendages. Then, the relationship among joint rates, elastic motion and the end-effector velocities is established by using the linear momentum and angular momentum conservation equations. Secondly, a closed-loop control system is designed based on the dynamic coupling model. And the control system is composed of target motion prediction, autonomous trajectory planning, energy-based joint controllers and so on. Thirdly, the energy-based joint control is detailed, which is proved to be stable by Lyapunov direct method. Finally, simulations of a planar space robot with two flexible appendages and a 3D space robot with single flexible appendage are provided to verify the effectiveness of the presented approach. The effectiveness of energy-based joint control for vibration suppression is verified by a single-degree-of-freedom space robot experimental system. The simulation and experimental results show that the space manipulator can successfully capture the moving target while suppressing the structure vibration.

Keywords: Space Robot; Flexible Appendage; Target Capturing; Vibration Suppression; Experiment System

1 Introduction

Robotic systems are expected to play an increasingly important role in future space activities such as repairing, upgrading, refueling and re-orbiting spacecraft. The autonomous target capturing, which has been successfully demonstrated by the Engineering Test Satellite VII (ETS-VII) [1] and

* Corresponding authors: wang.xq@sz.tsinghua.edu.cn (Xueqian Wang); liangbin@tsinghua.edu.cn (Bin Liang)