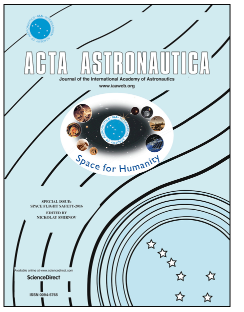

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PII: S0094-5765(17)30138-8

DOI: 10.1016/j.actaastro.2017.06.015

Reference: AA 6350

To appear in: *Acta Astronautica*

Received Date: 24 January 2017

Revised Date: 19 March 2017

Accepted Date: 15 June 2017

A Modified Modal Method for Solving the Mission-oriented Inverse Kinematics of Hyper-redundant Space Manipulators for On-orbit Servicing

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Abstract: A hyper-redundant space manipulator has extreme flexibility and is suitable to work in highly cluttered or multi-obstacles environment. However, its inverse kinematics is very challenging due to a large number of degrees of freedom (DOFs). In this paper, a modified modal method is proposed to solve the mission-oriented inverse kinematics. The spatial backbone of the manipulator is defined using a mode function, according to the mission requirement and working environment. All the universal joints are divided into $M/2$ groups, i.e. two adjacent universal joints comprise a group (M is the number of universal joints; it is assumed an even number. If it is an odd number, the remaining universal joint is a separated group). The whole manipulator is then segmented into $M/2$ sub-manipulators. Each sub-manipulator has 4-DOFs and is redundant for position or orientation. The last sub-manipulator is used to match the desired direction vector and the position of the end-effector with respect to the previous sub-manipulator's end. The remaining sub-manipulators are used to control the relative position between each other with one redundant degree of freedom. The equivalent link is fitted to the backbone function. The Cartesian coordinates of each node is then determined by combining the total length of the manipulator and the mode function. Then, the joint angles are solved through the position of each node. For each 4-DOF group, a parameter called arm angle is used to denote the redundancy and optimize its local configuration. Finally, typical cases of a 12-DOF and a 20-DOF manipulators are simulated. The results show that the method is very efficient for resolving the inverse kinematics of hyper-redundant space manipulators.

Keywords: Space Manipulator; On-orbit Servicing; Hyper-redundant Manipulator; Inverse kinematics; Mode Function

1 Introduction

A space robotic system will play an important role in on-orbital servicing [1-6], such as spacecraft construction, repair, maintenance [7] and orbital debris removal [8]. A hyper-redundant manipulator has great advantages when working in narrow and multi-obstacles environments. The redundancy can be used to deal with the singularity, obstacle avoidance and joint torque optimization problems synchronously. It is also useful for minimizing the reaction torque of a space manipulator.

However, the inverse kinematics of such manipulators becomes very complex and challenging,