Commun Nonlinear Sci Numer Simulat 17 (2012) 4901–4916

Contents lists available at SciVerse ScienceDirect

Commun Nonlinear Sci Numer Simulat

journal homepage: www.elsevier.com/locate/cnsns

Implementation of orbital attitude control laws on a nonholonomic platform

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ARTICLE INFO

Article history:
Received 17 June 2011
Received in revised form 17 February 2012
Accepted 28 May 2012
Available online 19 June 2012

Keywords:
Spatial robots
Dynamics analogy
Attitude control
Reduction by symmetry
Stability analysis

ABSTRACT

Equations of motion for a special system, intended to provide an experimental facility for application of spatial attitude control schemes, are studied in the modern setting of geometric mechanics. Imposed constraints and inherited symmetry existing in the system's dynamics structure help to resolve the Lagrange–D'Alembert principle into a set of reduced-order equations of motion.

On-orbit conditions are mimicked, permitting to evaluate feedback control algorithms for precise satellite manoeuvres in a laboratory situ but also to investigate stability issues due to complex rotational dynamics and interactions with flexible components. It is demonstrated that the same implications concerning gyro stability of the spatial system can be replicated as well on this prototype.

1. Introduction

Rigid body motion is one of the oldest and still interesting branches of classical mechanics. Subtle points of dynamics and of mathematical techniques owe their origin due to the study of rigid bodies and serve nowadays to explain many physical systems behaviour qualitatively. Moreover, the feasibility of spatial control methods implementable on satellites or spacecrafts is theoretically based on the frictionless and weightless environment of space. Those ideal conditions permit to plainly take advantage of multiple conservative laws naturally arising in this situation and subsequently lead to governing equations of reduced-order which facilitate the controller designing task.

On the other hand, testing hardware reliability and validating control algorithms constitute challenging issues that despite theoretical advances on the concept, is not feasible due to required conditions inaccessible in laboratory environments. Consequently, development of new spacecraft attitude control technology has depended instead on extensive analysis and simulation of spacecraft rotational dynamics. Immersed encapsulated prototypes [1,2] or models mounted on spherical air bearings [3–5] offer a nearly torque-free environment, meant to provide unconstrained rotational motion for ground-based research in spacecraft dynamics and control. But inconveniences exist such as undesired drag forces, the burden of accessorial equipments and the restricted spatial angular cone of the bearings that limits the range of rotation. Motivated by the aforementioned issues and in order to compensate the omni-presence of gravity surrounding ground laboratories, an attitude control test-bed shown schematically in Fig. 1, has been developed. This system is based upon a spherical platform constrained to roll on flat surface which allows experimenting manoeuvres involving continuous large angles, three-axis rotational motions. Concepts related to satellite attitude dynamics and control is meant to be studied through this device. The analogy established here between the orbital and ground-based prototypes will permit to implement and verify control

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http://dx.doi.org/10.1016/j.cnsns.2012.05.028