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ORIGINAL PAPER

# Exploring the analogy for adaptive attitude control of a ground-based satellite system

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**Abstract** Equations of motion for a special system pertaining to the class of mixed nonholonomic mechanical systems are studied in the modern setting of geometric mechanics. The presented attitude control test bed is intended to provide an experimental facility that, in certain senses, emulates the dynamics of on-orbit conditions in the laboratory site, allowing the evaluation of path planning and feedback control algorithms. This paper demonstrates the feasibility of the approach and proposes a concurrent solution to the attitude tracking control problem that, due to uncertainties of the parameters, is likely to require effective adaptive aptitudes. Moreover, the invariance with respect to Lie group actions of governing dynamics and measurable output readings has allowed the investigation of controllability and observability in an intrinsic manner.

**Keywords** Space robots · Dynamics analogy · Adaptive attitude control · Reduction by symmetry

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## 1 Introduction

Rigid body motion is one of the oldest and still interesting branches of classical mechanics. Subtle points of dynamics and mathematical techniques originate from the study of rigid bodies and serve nowadays to explain many physical systems behaviour qualitatively. The low gravity and frictionless background of space can serve as an ideal location to verify experimentally the viability of theoretical statements and principles without resorting to any further assumptions. In spatial robotic applications, those ideal conditions permit one to plainly take advantage of conservative laws naturally arising from existing symmetries derivable from Noether's theorem [1]. This fact, in turn, leads to a reduced-order derivation of governing equations or first integrals which facilitates the control design and numerical integration tasks. Nonetheless one has still to deal with some perturbations like the slow varying inertia properties or high-frequency vibrations, respectively, caused by fuel consumption or solar booms flexibility, hence deteriorating the ideal conditions. Whenever excited by internal or external sources, this latter source can induce large drifts in the base body orientation over long duration periods. Maintaining the system reliability against such disturbances to achieve precise pointing missions imposes severe requirements on controllers whose effectiveness has to be checked in a near-reality situation. One practical solution for testing hardware and validating attitude controllers could reside on indoor experiments but encounters fundamental difficulties as the