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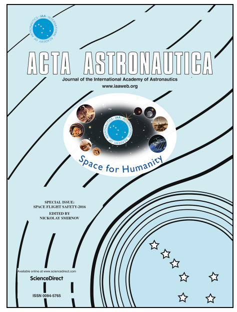

Extended state observer based robust adaptive control on SE(3) for coupled spacecraft tracking maneuver with actuator saturation and misalignment

Jianqiao Zhang, Dong Ye, Zhaowei Sun, Chuang Liu

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Extended state observer based robust adaptive control on SE(3) for coupled spacecraft tracking maneuver with actuator saturation and misalignment

Jianqiao Zhang, Dong Ye*, Zhaowei Sun, Chuang Liu

Research Center of Satellite Technology, Harbin Institute of Technology, Harbin, 150001, China.

Abstract

This paper presents a robust adaptive controller integrated with an extended state observer (ESO) to solve coupled spacecraft tracking maneuver in the presence of model uncertainties, external disturbances, actuator uncertainties including magnitude deviation and misalignment, and even actuator saturation. More specifically, employing the exponential coordinates on the Lie group SE(3) to describe configuration tracking errors, the coupled six-degrees-of-freedom (6-DOF) dynamics are developed for spacecraft relative motion, in which a generic fully actuated thruster distribution is considered and the lumped disturbances are reconstructed by using anti-windup technique. Then, a novel ESO, developed via second order sliding mode (SOSM) technique and adding linear correction terms to improve the performance, is designed firstly to estimate the disturbances in finite time. Based on the estimated information, an adaptive fast terminal sliding mode (AFTSM) controller is developed to guarantee the almost global asymptotic stability of the resulting closed-loop system such that the trajectory can be tracked with all the aforementioned drawbacks addressed simultaneously. Finally, the effectiveness of the controller is illustrated through numerical examples.

Keywords: Coupled spacecraft tracking maneuver; Actuator uncertainties; Anti-windup technique; Extended state observer; Adaptive fast terminal sliding mode controller.

1. Introduction

Traditionally, the modeling and control of translational and rotational motion of a spacecraft are described independently with the mutual couplings neglected, which leads to poor control results [1–3]. Consequently, in recent years, an increasing attention has been paid to the modeling and control of the six-degrees-of-freedom (6-DOF) motion considering the translational motion, the rotational motion, and their couplings to meet the requirements of some aerospace missions, such as spacecraft rendezvous and docking, capture of space targets, high-precision monitoring of the Earth and its surroundings, spacecraft formation flying, and on orbit servicing and maintenance of spacecraft, which need the translational and rotational tracking maneuver satisfied with high accuracy simultaneously[1–9].

In [4], the translational and rotational dynamics of the spacecraft considering the mutual couplings were modeled using vectrix formalism and the 6-DOF model in [5] was developed by combining the translational motion, the rotational one and the dynamical couplings all together. Though the models were considered in a united framework, the separate describing of position and attitude makes the controllers be complicated and reduces spacecraft's computational efficiency. In order to describe the model in a compact form and facilitate control design, both the 6-DOF model proposed in [1, 6] using dual-quaternion representation and the model in [2, 7] where the configuration tracking errors are described by exponential coordinates on the Lie group SE(3) were effective. It should be stressed that in these studies either without considering the

☆Corresponding author.
Email addresses: zhangjianqiao@hit.edu.cn (J. Zhang); yed@hit.edu.cn (D. Ye); sunzhaowei@hit.edu.cn(Z. Sun); liuchuangforever@msn.com(C.Liu).