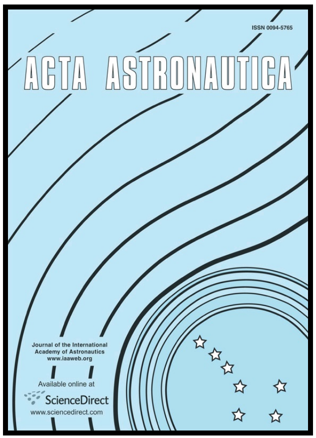

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Disturbance Observer-based Fuzzy Control for Flexible Spacecraft Combined Attitude & Sun Tracking System

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Abstract

This paper investigates the combined attitude and sun-tracking control problem in the presence of external disturbances and internal disturbances, caused by flexible appendages. A new method based on Pythagorean trigonometric identity is proposed to drive the solar arrays. Using the control input and attitude output, a disturbance observer is developed to estimate the lumped disturbances consisting of the external and internal disturbances, and then compensated by the disturbance observer-based controller via a feed-forward control. The stability analysis demonstrates that the desired attitude trajectories are followed even in the presence of external disturbance and internal flexible modes. The main features of the proposed control scheme are that it can be designed separately and incorporated into the baseline controller to form the observer-based control system, and the combined attitude and sun-tracking control is achieved without the conventional attitude actuators. The attitude and sun-tracking performance using the proposed strategy is evaluated and validated through numerical simulations. The proposed control solution can serve as a fail-safe measure in case of failure of the conventional attitude actuator, which triggered by automatic reconfiguration of the attitude control components.

Keywords: Flexible spacecraft, Attitude control, Sun tracking, Disturbance observer, Fuzzy control

1. Introduction

Most spacecraft systems today use a handful of actuators, namely, momentum exchange devices such as reaction wheels and control moment gyros, thrusters, and magnetotorquers to achieve three-axis attitude stabilization [1]. In these systems, thrusters and reaction wheels are often selected as their primary actuators to compensate for disturbance torques and to perform commanded slewing maneuvers. There are a few examples (EchoStar 5, FUSE, and Navstar 2-08) shown in [2], when one of the wheels suffers an irrecoverable failure, it may cause a spacecraft to lose its ability to maintain its attitude and thus potentially cause a mission interruption or a total loss. Other notable incidents include the loss of two reaction wheels on JAXA's Hayabusa, asteroid sample-return spacecraft [3]; unusual readings from one of the three reaction wheels detected on NASA's Mars Odyssey [4], planet Mars orbiter; the shutdown of one of the reaction wheels due to an internal friction issue in NASA's Dawn, protoplanets space probe [5]; and the mission abort on NASA's Kepler, exoplanet-hunting space telescope because two of its four reaction wheels were permanently disabled [6]. This unfortunate chain of events occurring in spacecraft in fact shows the promising benefits of developing a non-conventional backup actuator for the attitude control system.

Technically, the attitude can be recovered by firing a system of propulsion thrusters that control the total momentum of the spacecraft through expelling propellant to produce a torque around the center of mass. However, the undesired downsides of using a thruster are expendable propellants, increased payload mass, design complexity and cost [7]. To ensure operational sustainability, the leading choice for a resource-efficient approach is to employ the Solar Array Drive Assembly (SADA), because they require only electrical power, which can be provided by solar energy conversion. Nearly every spacecraft uses solar arrays to generate the necessary electrical power for their equipment, and these arrays have to be pointed toward the Sun continuously during sunlit phase to get normal incident sunlight onto the solar cells. The device provides the capability of rotating the solar arrays with respect to the spacecraft main hub [8]. In the 3-axis stabilized 2-wing geostationary satellite, one SADA controls the north panel and the other controls the south panel. The solar array is rate-servo controlled to rotate once per orbit by the