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Author: Mr. Insu Chang
University of Illinois at Urbana-Champaign, United States, chang162@illinois.edu

Prof. Joseph Bentsman
University of Illinois at Urbana-Champaign, United States, jbentsma@illinois.edu

ROBUST CONSTRAINED NONLINEAR FEEDBACK CONTROL FOR SPACECRAFT TRAJECTORY MANEUVER WITH COUPLED ORBIT AND ATTITUDE MOTION UNDER MULTIPLE FUEL SLOSH MODES

Abstract

Spacecraft trajectory maneuver, which is conventionally a subject of translational dynamics, has become one of the major topics in astrodynamics since spacecraft formation flying concepts emerged in 1980's. However, attitude motion needs to be considered as well in the trajectory maneuver due to the location of the thruster in a spacecraft and its angle constraint. Therefore, controlling the maneuver by considering attitude motion simultaneously is more complicated than conventional translational dynamics. This paper investigates a nonlinear feedback control technique for spacecraft orbit transfer and formation reconfiguration with coupled orbit and attitude motion.

In addition to the complexity of the dynamics for the trajectory maneuver, there are many types of disturbances to hinder the performance of the spacecraft control systems: gravity-gradient torque, magnetic fields, etc. for attitude motion and Earth oblateness, atmospheric drag, etc. for translational motion. While such disturbances can be mathematically formulated, the fuel slosh effect, caused by fuel consumption of a spacecraft, is hardly predictable and is one of the major disturbance sources in translational motion as well as the rotational motion of the spacecraft. It has been a challenging issue for a long time and many researchers have tried to handle the disturbance.

The main contribution of this paper is to suggest a robust nonlinear feedback control system for spacecraft trajectory maneuver with the coupled dynamic condition in 3-dimensional space in the presence of the fuel slosh effect. For generalization of the fuel slosh effect, multiple fuel slosh modes are considered. The new controller is based on our recent studies, called the constrained discrete-time state-dependent Riccati equation (CD-SDRE) technique [1,2]. In this paper, we consider the constraints on thrust (input saturation) and its direction expressed in the spacecraft body frame is considered when designing the control system. Moreover, the CD-SDRE technique is improved to handle model uncertainties due to the multiple fuel slosh modes. The stability proof of the proposed CD-SDRE feedback system is investigated by using input-to-state stability and Kharitonov's theorem. Simulation results of the spacecraft reconfiguration problem are provided to show the effectiveness of the proposed control system.

[1] I. Chang and J. Bentsman, "Constrained Discrete-Time State-Dependent Riccati Equation Technique: A Model Predictive Control Approach," 52nd IEEE Conf. Decision and Control, pp. 5125-5130, December 2013.

[2] I. Chang, J. Bentsman, S.-Y. Park, and C. Park, "Generalized Modeling and Robust Constrained Nonlinear Feedback Control for Spacecraft Attitude Maneuvers with Fuel Slosh Effect," AIAA SPACE 2014, (submitted).