ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics, Modelling and Determination (6)

Author: Mr. Sangwon Kwon
Osaka Prefecture University, Japan, kwon@aero.osakafu-u.ac.jp

Prof. Takashi Shimomura
Osaka Prefecture University, Japan, shimomura@aero.osakafu-u.ac.jp
Prof. Hiroshi Okubo
Osaka Prefecture University, Japan, okubo@aero.osakafu-u.ac.jp

POINTING CONTROL OF SPACECRAFT USING TWO SGCMGS VIA LPV CONTROL THEORY

Abstract

A control moment gyro (CMG) is a kind of actuator for spacecraft attitude control. In the case of smaller-sized satellites with limited resources, it is not a suitable option to increase hardware resources. Therefore, the problem of attitude control using a reduced number of CMGs has received considerable attention for decades and many studies to this problem have been performed in the previous decades in the area of underactuated spacecraft control [1],[2]. By using the law of angular momentum conservation, the objectives of pointing control of spacecraft using two single-gimbal control moment gyros (SGCMGs) are described as follows.

$$\begin{aligned} &\omega \to 0 \\ &\delta_e \triangleq \delta - \delta_f \to 0 \\ &\phi_e \triangleq \phi - \phi_f \to 0 \end{aligned}$$

where ω is the angular velocity of the spacecraft, δ is the vector of the gimbal angles of two SGCMGs, and ϕ is an Euler angle. The subscript f denotes the final state of parameters. To this control problem, we developed a switching controller that consists of a nonlinear controller based on the Lyapunov stability theory and an LQR controller in [1]. However, this switching controller is too complex, because it consists of multiple-steps. Therefore, in this paper, we develop another controller being simpler and more suitable than the former switching controller. In the development of this new controller, we propose a new method of pointing control using two SGCMGs via linear parameter-varying (LPV) control theory. The LPV control has advantages such that it provides guaranteed stability and performance over a wide range of varying parameters [3]. The nonlinear model of spacecraft using two SGCMGs in six degrees of freedom can be represented as an LPV system as follows.

$$\begin{aligned} \dot{x} &= A(\delta, \psi)x + B(\delta, \psi)u \\ u &= -K(\delta, \psi)x \end{aligned}$$

where the gimbal angle vector δ and the Euler angle ψ are both scheduling parameters. The state feedback controller is developed on the basis of a gain-scheduled control technique for the LPV system. The gain-scheduled control approach is to find a Lyapunov function which guarantees overall stability and performance of the close-loop system. The design condition of such a controller is described by a set of linear matrix inequalities (LMIs). The original non-convex problem is transformed into a convex one and the nonlinear parameter relationship is described as a bound of a convex region in a parameter space [4]. Approximating this region by a set of successive LMIs, the state feedback gain $K(\delta, \psi)$ is successfully

obtained. A numerical simulation demonstrates that the proposed method is highly effective for fast and stable pointing control of spacecraft.

References

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