Paper ID: 37348
student

ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations (IP)

Author: Mr. Yuki Akiyama
Kyushu University, Japan

Dr. Mai Bando
Kyushu University, Japan
Dr. Shinji Hokamoto
Kyushu University, Japan

QUATERNION BASED ATTITUDE STABILIZATION IN THE CIRCULAR RESTRICTED THREE-BODY PROBLEM

Abstract

Libration points and libration point orbits are often selected as locations for scientific missions. The attitude motion exhibits complex rotational behaviors when it is coupled to the three-body problem. Therefore, establishing an attitude stabilization method in the three-body regime is important to avoid undesirable tumbling. Many authors have studied the attitude dynamics at a libration point or on a libration point orbit in the circular restricted three-body problem (CRTBP) based on Euler angles to represent the attitude of spacecraft. However, these previous studies have focused on the attitude dynamics and the attitude control have not been fully established. In general, Euler angles cannot avoid singularity, and hence a quaternion representation and quaternion feedback is often used for attitude stabilization control of spacecraft. Hence, we propose an attitude stabilizing controller based on quaternion feedback for spacecraft orbiting in a libration point orbit in the CRTBP.

To derive the quaternion feedback for the CRTBP, we provide a port-Hamiltonian system with quaternion. Port-Hamiltonian systems are introduced as generalization of conventional Hamiltonian systems describing physical control systems with energy consumptions and are given by

$$\dot{x} = J(x,t)\frac{\partial H}{\partial x}^{\mathrm{T}}(x,t) + g(x,t)u \tag{1}$$

$$y = g(x,t)^{\mathrm{T}}\frac{\partial H}{\partial x}^{\mathrm{T}}(x,t) \tag{2}$$

where $x \in \mathbb{R}^n$, input $u \in \mathbb{R}^m$, output $y \in \mathbb{R}^m$, a skew-symmetric matrix $J \in \mathbb{R}^{n\times n}$, and the Hamiltonian of the system $H \in \mathbb{R}$. A port-Hamiltonian system can be transformed to another one by a generalized canonical transformation which is a set of coordinate and feedback transformations preserving the generalized Hamiltonian structure. If the new system is chosen to be passive, the system can be stabilized by a simple output feedback. Consequently, the stabilization and tracking control can be easily achieved by utilizing the passivity of the new system.

This paper presents a novel control method to stabilize an attitude of spacecraft at libration points or on libration point orbits based on generalization of passivity-based control. First, the attitude motion of a rigid spacecraft subject to three-body dynamics is formulated in port-Hamiltonian form using the quaternion as generalized coordinates. Then, the generalized canonical transformation is applied to the attitude control in the CRTBP. Specifically, we consider the following cases: (1) attitude stabilization at L_2 in the CRTBP, (2) attitude stabilization along L_2 Lyapunov orbits in the CRTBP, (3) attitude stabilization and station-keeping along L_2 Lyapunov orbits, (4) Sun-pointing attitude control and station-keeping along L_2 Lyapunov orbits.