Paper ID: 58931
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (1) (1)

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FORMATION CONTROL USING DIFFERENTIAL ATMOSPHERIC DRAG CONSIDERING ATTITUDE CONSTRAINTS

Abstract

The formation flying is a key technology in future space science missions. One of the challenges for implementing formation flying is to maintain the formation by utilizing environmental forces under various perturbing factors. In Low Earth Orbits (LEOs), utilizing aerodynamic drag is a possible control action for maintaining formation. The relative motion of satellites in a circular orbit based on Hill-Clohessy-Wiltshire equation is not sufficiently accurate, because J2 perturbation has dominant effect. Thus, Schweighart and Sedwick derived a more accurate relative equation of motion including a J2 term: Schweighart-Sedwick (SS) equation.

The application of atmospheric drag as a driving force of formation control has been studied by using the SS equation. Cho et al. (JGCD, 2016) showed that rendezvous is achievable by using the difference in atmospheric drag between the two satellites. Shouman et al. (JGCD, 2019) proposed to utilize the differential atmospheric drag along with the thruster to cancel the J2 term in formation flying mission. In these papers, the orbital dynamics of the satellites is assumed to be independent from the attitude dynamics. However, in utilizing atmospheric drag, the attitude motion is strongly influential to the orbital dynamics. This paper considers the formation flying based on the SS equation by using the atmospheric drag as a main control force. First, we incorporate the attitude-dependent differential atmospheric drag force model into the SS equation. Then the coupled attitude-orbit dynamics are derived and control torque to achieve the desired formation is designed. This system has difficulties to control: two different motions exist where the orbital motion is indirectly controlled by the attitude-dependent differential atmospheric drag and the attitude is directly controlled by the control torque. Moreover, different time-scale exists for orbital motion variables and attitude motion variables. In this study, we decouple the orbital motion (slow variables) and attitude motion (fast variables) to design a controller based on the singular perturbation method by which motion with different response can be separated and the order of the equation is reduced. Then a linear quadratic regulator theory is adopted to design of control input to satisfy physical constraints of attitude-dependent differential atmospheric drag in a systematic manner. Finally, the simulation results are shown to demonstrate the proposed method.