Paper ID: 86693
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (2) (2)

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POINTING ACCURACY USING MODEL PREDICTIVE CONTROL-BASED GUIDANCE CONTROL FOR DESTINY+ FLYBY MISSION

Abstract

In recent years, the importance of autonomous control is increasing due to the enhancement of the complexity of spacecraft missions. The DESTINY+ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) is a science and technology demonstration mission to asteroid Phaethon, the parent body of the Geminid meteor shower. It will explore the asteroid during a flyby, and conduct scientific observations of cosmic dust, which is considered as a source of the organic material on Earth. This mission will demonstrate technologies that will enable future low-cost and high-frequency deep space exploration. In the DESTINY+'s mission, the most critical technology for mission success lies in reliable execution of flyby observation in one-chance mission that cannot be repeated, in which the DESTINY+ can only observe once when it passes by the asteroid Phaeton. In other words, hybrid control system and its robustness are important in reliably performing flyby observations by combining the satellite attitude (three axes) and the gimbal angle control (single axis) of the mission camera TCAP (Telescopic Camera for Phaethon).

When conducting flyby observation in deep space while achieving high precision pointing control performance, a pointing control system is required that allows the spacecraft to autonomously navigate its relative position to the asteroid Phaeton based on the observation data. The basis of asteroid relative position navigation is to estimate the spacecraft position relative to the current asteroid position based on observed data. In addition, to achieve highly accurate pointing control performance when passing an asteroid, it is required to predict the near future state based on nonlinear optimal control theory and control so that the pointing error is minimized when passing each other. At the time, the spacecraft attitude and camera gimbal angle are autonomously controlled in real time while performing real-time optimization considering the actuator and other constraints. In this paper, we build a model predictive control-based guidance control algorithm after modeling the spacecraft, considering the constraints of the sensor and actuator, and evaluate the pointing performance of the mission camera TCAP based on a real-time optimization algorithm through numerical analysis. This shows the feasibility of the pointing performance that is essential for the mission success. In addition to the numerical simulation, test results using the TCAP prototype model and the results of comprehensive pointing performance at the spacecraft system level, considering the effects of attitude control, vibration disturbance, etc. are presented.