IAF ASTRODYNAMICS SYMPOSIUM (C1)
Virtual Presentations - IAF ASTRODYNAMICS SYMPOSIUM (VP)

Author: Dr. Feng Zhang
China Academy of Launch Vehicle Technology(CALT), China

CAPABILITY ANALYSIS FOR MANIPULATOR-ACTUATED INTEGRATED TRANSLATIONAL AND ROTATIONAL CONTROL STRATEGY OF SPACECRAFT

Abstract

Accurate position and attitude control is of great importance for space missions, especially proximity operations. With a unified consideration of translational motion and rotational motion, integrated control becomes a natural and preferable approach to reach a better performance, and has gained attentions for years. Viewing actuators for integrated control, present works often utilized thrusters to provide necessary forces/torques via reaction effect. However, the thruster-actuated control performance is greatly restricted due to the actuator nonlinearities of thrusters. To tackle this, novel actuation ways become increasingly attractive. Note that, in proximity missions, space manipulators are often mounted on the spacecraft to finish required operations in free-floating working mode, during which the position and attitude of the spacecraft would be changed by manipulator motions due to momentum conservation. Inspired by this characteristic, manipulator would be an appropriate actuator to conduct position and attitude control of the spacecraft, for saving un-renewable fuel and making full use of better linearity and satisfactory dynamic performance of joint motion. A similar philosophy had been verified in JAXA's ETS-VII mission, where the attitude was stabilized by pre-designed manipulator motions. A further development of such philosophy that integrated translational and rotational motion of a spacecraft actuated by manipulator has been proposed and studied in recent years.

The present study mainly analyzes the capability of such manipulator-actuated integrated translational and rotational control strategy. Firstly, the coupled translational and rotational kinematics of spacecraft with multiple manipulators is developed due to momentum conservation. To provide adequate control force/torque, a necessary condition for control allocation is given to assist manipulator configuration design. In what follows, two control gains are analytically derived to represent control capabilities for translation motion and rotational motion, respectively. The control gains possess highly nonlinear functions with various factors including manipulator configurations, dimensions and mass properties of the spacecraft and the manipulators, respectively; furthermore, rotational control gain is also affected by the yaw attitude of the spacecraft. Then, the control capability is analyzed via multiple simulations with different aforementioned factors. The simulation results indicate that 1) space manipulator enables the integrated translation and rotation of the spacecraft, but possesses a limited capability for translational regulation; 2) dual manipulator-actuated strategy holds a better control capability than that of single manipulator-actuated scheme; 3) mass ratio of the spacecraft to the manipulator affects the control capability to a great extent. Finally, several applicability proposals are given for the proposed manipulator-actuated control strategy.