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ESTIMATION OF SOLAR RADIATION PRESSURE FORCE FOR SOLAR SAIL NAVIGATION

Abstract

This paper investigates the solar sail modeling and its estimation approach of solar sail navigation. Estimation of solar sail force model in space is the key factor for successful solar sail navigation because the solar sail may have a large uncertainty due to the flexible membrane. Since the sail wrinkles after a deployment of the sail and its surface will suffer from degradation, the solar sail force model is difficult to develop before the launch. In this paper, a practical analysis of estimating the solar sail force model using radiometric observable is investigated. This is demonstrated by orbit determination including parameter estimation of generalized sail model.

Estimation of solar sail force means a parameter estimation of solar sail model. A generalized sail model (GSM) allows for the analytic computation of forces and moments acting on a solar sail of arbitrary fixed shape. These forces and moments are computed analytically using a set of coefficients, assuming the sail remains fixed with attitude. Since, some of solar sail concepts are composed by flexible membrane, a sail may have a large uncertainty due to the deployment after the launch. In this study, the radiometric tracking data (range, Doppler and delta-DOR observable) are used to estimate the GSM. Estimating the GSM parameters using tracking data could inform the actual acceleration due to the solar sail in space.

The GSM could adapt to the uncertainties by estimating its parameters, though it requires the long term tracking data including various attitude of the sail with respect to the Sun. It's because some of the parameters could not distinguish without the deviation of solar sail force with respect to the sail's attitude. In this study, several sequence are demonstrated to investigate better way to estimate the solar sail model for its navigation.

We also demonstrated this estimation approach using the sequence of actual solar sail mission planned by Japan Aerospace Exploration Agency. Since the actual solar sail missions are restricted by power, communication and heat condition, the attitude sequences are limited and solar sail navigation could be much difficult. The practical estimation approach for solar sail force model is illustrated considering the sail's deformation and distribution of optical properties. The simulation is implemented by means of realistically simulated radiometric tracking data. The performance of using generalized sail model is clearly described with the simulation.