On-orbit Estimation of Optical Property by Precomputed Tensor Method for High-fidelity SRP Model

Satoshi Ikari,[1*] Kakeru Tokunaga,[1] Takahiro Ito,[2] Takaya Inamori, [3] Ryu Funase,[1] and Shinichi Nakasuka[1]
[1]*The University of Tokyo, Japan;* [2]*JAXA, Japan;* [3]*Nagoya University, Japan;*
ikari@space.t.u-tokyo.ac.jp

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Solar Radiation Pressure (SRP) is a major disturbance force and torque for spacecraft in the high altitude earth or in the interplanetary orbits. In order to calculate accurate SRP, high-fidelity polyhedron modelling methods have been proposed by recent researchers [1]. The methods can calculate accurate SRP including effects of shadows on the surfaces casted by other surfaces. Since the calculation cost of these accurate methods is too high to be used in a practical astrodynamics analysis, usually, SRP forces or torques of certain sun vectors are precomputed, and the data set of the forces or torques is stored as a data table or is expanded to coefficients corresponding to a certain function as an approximation. Although the table or the approximated coefficients can be used to compute accurate SRP in a short computation time, the methods still have several issues for more practical usage. One of the issues is that the methods cannot be used to estimate optical properties of each surface which are most uncertain parameters in a SRP calculation, because the modelling methods do not separate geometrical information and optical properties. The estimation method is a key technology to correct numerical models including uncertainties to suit on-orbit results. The conventional methods can correct the approximated coefficients to fit on-orbit results. However, the coefficients are not suitable for the estimation because they do not have any constraints (e.g., the number of coefficients and the limitation of their value). Some optical property estimation methods have been discussed, but these methods focus on low-fidelity geometrical models and do not consider the shadow effect [2].

In order to construct a high-fidelity SRP model, which can estimate optical properties, authors have proposed the precomputed tensor method [3]. The proposed method precomputes and approximates the visibility functions of each surface instead of total SRP force or torque acting on spacecraft. The visibility function is a binary function on the unit sphere and represents whether a ray from a certain sun vector can reach to the surface or not. The approximated coefficients for the visibility functions are handled as tensors, and precomputed tensors which can be obtained from only geometrical information are calculated. The SRP force and torque equations can be expressed as tensor form equations by using the precomputed tensors. The proposed method completely separates the geometrical information and optical properties by using the precomputed tensors. Thus the method can be used for an optical property estimation of high-fidelity SRP models.

In this study, the proposed method is applied to an actual on-orbit spacecraft analysis for verification of the effect of the method. Flight data of PROCYON, which is a 50-kg class interplanetary micro-spacecraft developed by authors and launched in Dec. 2014, is analysed. In the PROCYON mission, SRP torques at many sun vectors were measured on orbit for SRP modelling studies, and the measured SRP torques are used for verification and the optical property estimation of the proposed method. The precomputed tensors for the proposed method are calculated from the real CAD data of the PROCYON project by using the newly developed tensor calculation tool. The optical properties of material used in PROCYON are also measured on ground to compare with the estimated values. This paper introduces a process of the precomputed tensor calculation, a method for the optical property estimation, and the result of the on-orbit estimation by using the PROCYON data. The estimated results are compared with on-ground measured value, and the comparison reveals the effect of the proposed method and some issues for more accurate orbital disturbance modelling.

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