Simplified Covariance Estimation and Target Observation Management Method for On-Board Optical Navigation of Deep Space Probe

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A simplified covariance estimation and target observation management method for on-board optical navigation in deep space is focused on in this paper. Range and Range-Rate is one of orbit determination (OD) methods, which is the most general method to determine the position and velocity of spacecraft in deep space. This method has been used for a long time because of its high reliability and the performance of OD. However, this radio-based navigation approach has several problems, such as the necessity of a large antenna and regular operation. On the other hand, the interest in small spacecraft is increasing because of its high-frequency launch, low manufacturing cost and so on. However, the size of spacecraft does not depend on the operation cost, burdens and the size of antennas. Further, when a number of spacecraft are launched into deep space, problems described above will be more serious. Therefore, the on-board decision by spacecraft comes to be important to solve these problems [1]. This paper focuses on on-board OD particularly.

The proposed on-board OD is that spacecraft observes celestial bodies in the solar system, such as planets and asteroids, with an ONC (Optical Navigation Camera) and determines its trajectory using O-C which is the difference between observation and computation. The knowledge about the precise state of bodies based on long-time observation from the ground makes on-board OD possible. The selection of bodies to observe is important for effective OD, which increases the observation time for the mission. However, the covariance analysis about all observation candidates and the whole mission period is unrealistic due to computational cost and time. To find the optimal observation bodies and estimate OD accuracy at an arbitrary time, we propose the method using the geometric arrangement of spacecraft and observation bodies. This method consists of the estimation of error ellipsoid and its superposition; an expected error ellipsoid of OD can be estimated using the geometric arrangement, observation accuracy of an ONC and the number of observation data without complex calculations in the case that spacecraft observes a certain body. The merits of the proposed method are as follows: observation selection for the effective error reduction about an arbitrary axis and easy error management (when and what to observe). Fig.1, 2 show the orbital configuration and the results of the covariance analysis and proposed method respectively. Optimal observation bodies are an asteroid and Mars inside an orange circle in Fig.1. A certain level of agreement between two methods is found regardless of the observation and non-observation period. The detail method and results will be presented along with the body selection and observation timing for a certain OD accuracy.

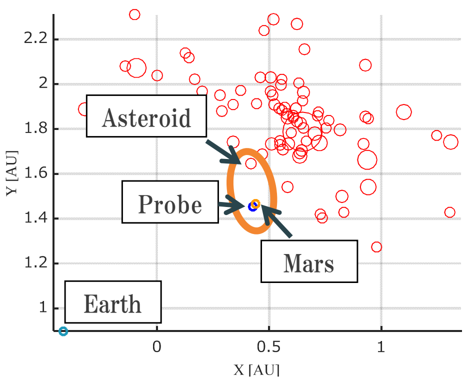

Fig. 1. Orbit configuration.

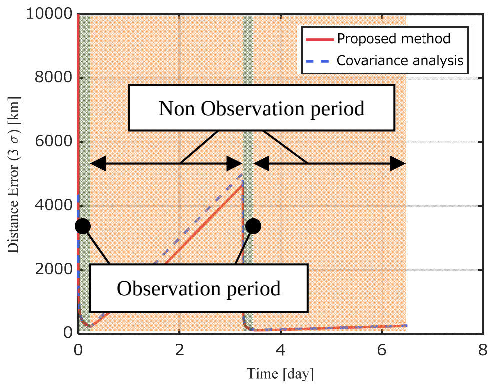

Fig. 2. Error Estimation by proposed method and covariance analysis.

References

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