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NEW APPROACH FOR ESTIMATION OF ASTEROID'S INTERNAL STRUCTURE WITH IMAGE-BASED SHAPE MODEL

Abstract

In asteroid exploration, highly accurate navigation of a spacecraft is required especially when the spacecraft is descending to or landing on the asteroid's surface. But most asteroids have voids within themselves. For example, the bulk density of the near-Earth asteroid Itokawa, as investigated by the Hayabusa spacecraft, is about 40%, considering LL ordinary chondrites are reasonable analogs for Itokawa's composition. Hence, to realize highly accurate navigation, it is necessary to obtain information related to the internal structure, or the gravity distribution of target asteroid before a spacecraft operation in vicinity of the asteroid is conducted, because the gravity filed strongly depends on the distribution of interior voids. Commonly used approach for estimating gravity field is to insert a spacecraft into an orbit around an asteroid, measure acceleration acting on the spacecraft and determine spherical harmonic coefficients. But, the approach is not always applicable to any asteroid exploration mission, because of the risk of the orbital insertion and constraint of time spent around an asteroid. In fact, Hayabusa's mission conducted descending and landing operations without the estimation of gravity distribution and assuming that Itokawa has a uniform density distribution.

In order to improve accuracy of spacecraft navigation in vicinity of an asteroid surface, this paper proposes a new approach to estimate the gravity distribution without any entry into an orbit around an asteroid and measurements of spacecraft motion.

The proposed method focuses on the relation in shape between an equipotential surface (Zero-Velocity surface) and an asteroid surface which can be computed by the shape model constructed by images obtained by spacecraft observations. On the assumption that the shape of an asteroid surface would gradually coincide to that of equipotential one with time by shaking caused by impacts or planetary encounters, the shape of the equipotential surface computed from an actual inner density distribution should be equal to, or very close to the shape of an asteroid surface. Based on the idea, we introduce the standard deviation of the values of zero-velocity on an asteroid surface as the estimation index, to evaluate the similarity in shape between an asteroid surface and equipotential one. And, we define the inner structure which minimizes the value of the estimation index as the solution in the proposed approach.

This paper reveals that the inner structure of Itokawa by the proposed approach and also discusses the way to improve navigation accuracy with the estimation result.