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Author: Mr. Zhonghuai Yan
Beihang University, China

Dr. Yuying Liang
ISAS, JAXA, China

AUTOMATIC LANDING-INFORMATION-BASED RECONSTRUCTION OF INTERNAL STRUCTURE FOR SMALL BODIES: MMX CASE

Abstract

Understanding the internal structure of small bodies provide significant information on in-situ resource distribution and sampling sites for sampling missions. However, the current technologies do not support real-time automatic reconstruction of small bodies' interiors. In particular, the sampling tasks including sampling site and material are evaluated in the pre-mission phase using remote observation (e.g., HST) while the internal structures are reconstructed in the post-mission phase using massive gravity data (see Dawn team's work, e.g., Park et al. 2014). Once the predicted resource distribution is deviated with the real one, the success (or the efficiency) of the sampling task is not guaranteed for no real-time information on the interiors is feedbacked to update the second sampling. It's one of the bottleneck constraints to space resource development. Thus, this paper develops real-time reconstruction of internal structure of small bodies based on landing segment of spacecraft and the update of sampling process is accomplished in MMX case.

First, the initial interior is assumed to be homogenous at bulk density as an anchor and 10^3-10^4 finite spherical elements are parameterized by its location, size, and density, which are then patched to the initial model. The real landing segment is supposed to be deviated from the nominal landing one by the unmodelled heterogeneous density distribution, i.e., the finite spherical elements. The dynamical mapping implicitly follows the transversal time flow, which results in the fundamental difference of our method from the physics-informed data-driven approaches (Izzo and Gómez 2022, Martin and Schaub 2022) using the gravitational PDEs. Similar to the classic batch least-squares filter, their approaches unavoidably request massive data to build up the whole gravity field so that the interiors can be estimated. However, our method extracts information from both the observed position state and its a-priori deviation at the time flow, accelerating the reconstruction process exponentially (related to the observation epoch number) according to our preliminary tests. Thus, it is able to provide a real-time automatic reconstruction of interiors by a single landing segment. Furthermore, the recurrent-flow neural networks (RFNNs) are adopted to approximate the implicit dynamical mapping and the distribution of the finite spherical elements is iteratively determined by minimizing the errors of the state transition matrix at each observation epoch. Finally, our method is applied to landing on Stickney crater in MMX case and scenarios with/without the second landing are tested by checking if the crustal height at designated site exceeds sampling depth.