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SMALL-BODY GRAVITATIONAL MODELING FOR ON-BOARD OPERATIONS AND MASS DISTRIBUTION ESTIMATION: TRADE-OFF ANALYSIS AND NOVEL APPROACH

Abstract

The modeling of small planetary bodies remains an active and challenging field of research for the deep-space community. Current efforts include, amongst others, the development of computationally-efficient methods to evaluate the gravitational field around irregular-shaped bodies (which also limits the feasibility of autonomous close-proximity operations), and the estimation of internal mass distribution from *in-situ* gravitational measurements.

This paper compares the performance of existing methods for the evaluation of small-body gravitational fields: (a) polyhedral model, (b) spherical harmonics, and (c) mascon-based models (uniform grid, optimized distribution, and unstructured and structured tetrahedral meshing), and proposes a novel approach for the optimization of mascon distributions based on Newton's method and an approximation of the inverse problem.

Preliminary results show that unstructured tetrahedral meshes can reduce modeling errors by 50% relative to classical uniform grids, or, alternatively, fewer mascons are required to achieve the same levels of accuracy (thus reducing computational demand and memory footprint). When further reducing the number of mascons (below 200), a structured meshing technique (generating tetrahedrons from each face of the polyhedron) shows 15% accuracy improvements relative to unstructured tetrahedral meshes.

Most significantly, however, the proposed approach for mascon optimization provides performance improvements of approximately one order of magnitude over state-of-the-art meshing techniques (in terms of computational efficiency, memory footprint, and accuracy), and thus exhibits potential for on-board close-proximity applications. The proposed method is also applied to the problem of estimating small-body internal mass distributions, and its performance is compared to that of the more conventional spherical-harmonics approach. Advantages and limitations of the proposed approach are thoroughly discussed in this study.

This paper, thus, provides a comprehensive comparison of existing approaches for small-body gravitational modeling, it proposes a novel and promising approach for the optimization of mascon distributions, and it demonstrates its potential for computationally-efficient on-board applications and small-body mass distribution estimation.