EGU24-1294, updated on 02 May 2024
https://doi.org/10.5194/egusphere-egu24-1294
EGU General Assembly 2024

Voxel-based Density Models for Accurate Gravitational Field Computation

Benjamin Haser, Thomas Andert, and Roger Förstner
Institute of Space Technology & Space Applications, Universität der Bundeswehr München, 85579 Neubiberg, Germany

Asteroids and moons are promising targets for physical space exploration. The use of physically-based simulations within a virtual environment for (deep) space missions can significantly benefit the testing and validation of guidance, navigation, and control algorithms. This approach offers advantages in terms of cost and time efficiency. Especially for orbit propagation and landing maneuvers, information about the gravitational field is crucial. However, several factors contribute to the complexity of this task, such as limited information available about the inner structure of celestial bodies. The lack of detailed knowledge about their shapes further adds to the challenge.

This study presents a voxel-based mass concentration (MASCON) method to model detailed and realistic density distributions, enabling accurate gravity field determinations. We chose a cube with constant density as first case due to the perfect shape reconstruction and the availability of an analytical solution for its gravity field. To validate our results, we calculated the surface gravity and compared it with the analytical solution, ensuring the accuracy of our calculations. Furthermore, the surface gravity is derived for different resolutions and compared against other state-of-the-art methods like the polyhedral method that provides a closed-form analytical solution of the gravity field for homogeneous density. The other two methods for validation also use a MASCON approach, one utilizing polydisperse sphere packing and another with MASCON represented in spherical coordinates. The relative errors of the gravitational acceleration between the four methods will be evaluated for a cube and sphere, with homogeneous density.

The second aspect of this study was to create a tool that generates realistic density distributions. We are able to successfully reproduce natural environments by placing body-specific restrictions on three-dimensional Perlin noise with additional normalization. The simulator can add the following structural features to the density distribution: an arbitrary number of centralized or decentralized shells, with varying thickness and densities, anomalies of arbitrary size and shape, only restricted by its maximum permille of the body's volume. Furthermore, we implemented different normalization techniques to keep the mass of all generated bodies fixed. Our results show that the tool can generate realistic density distributions and calculate the corresponding gravitational field correctly. The data generated here is used to train Machine Learning and Deep Learning algorithms for gravity inversion.