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# NON-UNIFORM GRAVITY FIELD MODEL ON BOARD LEARNING DURING SMALL BODIES PROXIMITY OPERATIONS

**Abstract**

Proximity operations about asteroids are challenging because of the non-uniform gravity field that they generate, which is largely unknown even during the proximity operation phase. Much of their characterization, in fact, is based on in-situ observations: mass is estimated thanks to flybys, while imaging the asteroid under various lighting conditions enables the reconstruction of the shape model and the determination of the spin rate. This allows ground controllers to understand the body's gravitational field, identify a model and safely guide the satellite. Moreover, hovering and imaging the body are fundamental science phases, to characterize the small object composition and nature, and the gravity field reconstruction plays a fundamental role in the remote science data fusion and scientific knowledge of the specific object enhancement.

Those operations became challenging in case the orbiting platform is a microsatellite, a CubeSat or, in general, a platform with reduced communication capabilities to ground. Even more challenging is the case is which a distributed system of platforms (such as a swarm of CubeSats) is considered and a relatively high autonomy is required.

This paper proposes a new approach to reconstruct the gravity field of either unknown or partially known objects using a modified Hopfield Neural Network (HNN). In particular, the gravity field of the object is represented through a spherical harmonics expansion the coefficients of which must be estimated. In general, the parametric identification of these coefficients can be written as an optimization problem. HNNs for parametric identification have been extensively studied in past years: this work, starting from the methodology state of the art, steps forward by extending their application to a new scenario and tuning them for online running; the gravity field coefficients are identified in flight and on board, by means of a specifically tailored HNN. Due to the inherent structure of the HNN, the procedure is computationally fast and light so that it can be used on board of small satellites or CubeSats. Moreover, the on-board and online reconstruction of the gravity field of the body can be used as the basis for an autonomous guidance of the platform, guaranteeing higher autonomy with respect to traditional methods.

The paper presents the modelling approach and the learning core settling and critically discusses the results output by the validation campaign. The effectiveness of the proposed approach is also presented through the results of simulations run on different dynamical environments to assess the network performances.