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HIGH-PRECISION SURFACE FORCE MODELLING APPROACH FOR SPACE-BASED FUNDAMENTAL PHYSICS MISSION

Abstract

As a part of the high fidelity satellite dynamics simulator, named XHPS (eXtended High Perfromance satellite dynamics Simulator), sophisticated surface force computation method has been implemented and illustrated in this contribution. Precise modelling and analysis of the surface forces acting on the satellite are the key elements needed for orbit propagation and future mission design.

The magnitude of the surface force depends on several factors, e.g. solar radiation pressure is governed by the intensity and the direction of the incident Sun as well as the surface properties and the illumination condition reflecting physical geometry.

Conventionally for disturbance estimation, a reference satellite area with average reflection coefficients is used for simplicity. However, demanding future missions are pushing the accuracy requirements down where the simplification is no more adequate. The general measure to achieve the high fidelity surface force computation is to adopt the finite element model (FEM) which describes the detailed geometry of the satellite structure incorporating a variety of material properties.

Several methods have been studied to obtain appropriate surface forces utilizing FEM, for example, ray-tracing. The FEM approach provides the highest fidelity results of the solar radiation pressure regarding the detailed geometry. Moreover, its generic nature accepts other non-gravitational disturbance computations, such as the albedo and infrared radiations from Earth and the air drag. The major bottleneck of the FEM approach is the computational load, and this contribution introduces the smart implementations of the surface force computation in XHPS.

Two different approaches have been implemented: the barycentric algorithm and the spherical location algorithm. The former emphasizes to improve the computation speed by generating the lookup table offline as a pre-process. On the other hand, the latter implementation computes the exposure condition online achieving exact solutions of surface forces.

Both implementations aim to achieve the highest accuracy and speed with slightly different emphasis. Although, each method requires certain compromise and the trade is shown by comparing several computational performance indices. For illustration, we adopt the mission scenario and satellite model of GRACE (Gravity Recovery And Climate Experiment).

The preliminary results show the efficiency boundary between the approaches in terms of the total computation time. In addition, a simple conclusion obtained that the spherical location algorithm is preferable in most cases, except for the severe requirement for a large memory access.