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SPACECRAFT RADIATION PRESSURE USING COMPLEX BIDIRECTIONAL-REFLECTANCE DISTRIBUTION FUNCTIONS ON GRAPHICS PROCESSING UNIT

Abstract

Effective orbit determination, maneuver and mission design, and numerical mission simulations require tools that enable accurate modeling of a spacecraft's dynamics. Radiation pressure (RP) from sources including solar, Earth infrared, planetary albedo and spacecraft thermal becomes a significant and dominant non-conservative force above Low Earth Orbit (LEO). As a result knowledge of the resultant forces and torques upon a body due to these dynamic effects are a primary consideration in the modeling and analysis of spacecraft operating above LEO and in deep space.

Current analytical RP evaluation approaches typically lump spacecraft shape and surface optical properties into a few or even a single parameter. The Cannonball model is a prime example of such an analytical approach. Increased modeling accuracy is often achieved by employing a numerical modeling approach where the spacecraft is approximated by multiple surface facets.

The presented modeling approach employs a computationally fast parallel ray-tracing algorithm to resolve the RP forces and torques over a spacecraft model defined as an articulated triangulated mesh. The parallel ray-tracing algorithm is implemented using the Open Computing Language (OpenCL) parallel computing tools to evaluate the spacecraft RP on the Graphics Processing Unit (GPU). The ray-tracing approach implicitly resolves spacecraft self-shadowing, arbitrary time varying spacecraft articulations and material properties, and multiple radiation sources (sun and planetary albedo).

Many of the common analytic and numerical modeling approaches use parameters to provide rough approximations of the specular, diffuse and absorption characteristics of the surface-radiation interactions. Notably, the ray-tracing method presented makes use of the significant amount of pre-launch engineering data available and employs bidirectional reflectance distribution functions (BRDF) to provide physically realistic modeling of surface material-radiation interactions. A BRDF defines the unique characteristics of how the diffuse and specular components of light are reflected from each surface. Typical RP evaluation methods trade generality in the computation of the resulting dynamics for computational tractability and speed. The method presented maintains generality by using BRDFs to resolve the RP dynamics while maintaining faster than real-time model evaluation computation time.

This paper demonstrates how complex RP forces and torques can be resolved more accurately and at high computational speed using a GPU focused methodology. Increased material fidelity is achieved by resolve surface characteristics with BRDFs informed by pre-launch engineering-data. Model validation has been accomplished and spacecraft numerical simulation shall demonstrate the methods ability to capture the many time varying characteristics of a spacecraft's dynamical state with greater accuracy.