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PARALLEL SPACECRAFT SOLAR AND THERMAL RADIATION PRESSURE MODELING USING GRAPHIC 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. Solar radiation pressure (SRP) and thermal radiation pressure (TRP) become respectively, dominant and significant, non-conservative forces above Low Earth Orbit (LEO). As a result knowledge of the resultant forces and torques upon a body due to these dynamic effect are a primary consideration in the modeling and analysis of spacecraft operating above LEO and in deep space.

Current analytical SRP and TRP 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. However, the time varying spacecraft articulations, materials properties and multiple radiation sources (sun and planetary albedo) are dependent on the myriad spacecraft control inputs and constraints. It is evident then that a method of SRP and TRP evaluation characterized by an ability to include time varying material and spacecraft state information has potential for a wide range of applications.

The developed method computes the discretized SRP and TRP forces and torques, over a spacecraft model defined as an articulated polygon mesh. Additionally the mesh is assigned material definitions describing the spacecraft surface diffuse, specular and absorptive radiation properties. An increased mesh density provides a more accurate SRP and TRP evaluation.

The method utilizes Open Graphics Library (OpenGL) and Open Computing Language (OpenCL) parallel computing tools to compute the SRP and TRP dynamics. The OpenGL rendering pipeline, is divided into stages where each stage in turn operates on the result of the previous stage. For each pipeline stage many thousands of parallel instances of a stage are executed, each performing processing on a single spacecraft mesh facet. The modeling approach accommodates spacecraft self-shadowing, arbitrary time varying spacecraft articulations and material properties, and multiple radiation sources (sun and planetary albedo).

This paper demonstrates how complex SRP and TRP forces and torques can be resolved more accurately and at high computational speed using a GPU focused methodology. Model validation has been accomplished and the inclusion of the approach in the spacecraft simulation tool Basilisk will demonstrate the ability of the approach to capture the many time varying characteristics of a spacecraft's dynamical state.