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OPTIMIZATION OF SPHERE POPULATION FOR ELECTROSTATIC MULTI SPHERE MODEL

Abstract

The use of electrostatic (Coulomb) actuation for formation flying is attractive because non-renewable fuel reserves are not depleted and plume impingement issues are avoided. Previous analytical electrostatic force models have assumed spherical spacecraft shapes, with mutual capacitance and induced effects included. However, this does not capture any orientation dependent forces or torques on generic spacecraft geometries encountered with very close operations and docking scenarios. The Multi Sphere Model (MSM) uses a collection of finite spheres to represent a complex shape and analytically approximate the Coulomb interaction with other charged bodies. This allows for six degree of freedom electrostatic simulations of relative spacecraft motion are possible in real time, which is crucial for the development of robust relative position and orientation control algorithms in local space situational awareness applications.

Current schemes to populate a geometry with optimal representative spheres rely on a nonlinear fit that matches the forces and torques from a truth model (a higher order finite element electrostatic solver) at various separation distances and geometries. One drawback of this approach is the necessity for an external shape to generate forces and torques. Another limitation is that, despite implementing symmetry arguments, the nonlinear fit is not robust for increasing numbers of spheres. Since all the charge on a conductor resides on its surface, a new method is proposed that populates the surface of a geometry with numerous spheres, so as to match the surface charge density determined by a higher order model. If uniform population schemes produce successful results, the complicated nonlinear parameter fitting process can be avoided. It is possible to compare the surface charge density of a cylinder from a finite element analysis software suite and the charge on the spheres in a representative MSM. Verification of this new form of the MSM requires that the correct forces and torques result when an external object is introduced. Because more spheres can be introduced with this approach, higher fidelity is possible in the prediction of electrostatic interactions. Moreover, the MSM can hereby be used to model charged membranes in space, which have potential applications in radiation shielding and other inflatable structures.