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Importing CAD-Generated Device Geometry to the Neptune EM-PIC Simulation Code

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The 3D Electromagnetic Particle-in-Cell (EM-PIC) method is well known as a powerful simulation technique for modeling electron beam and/or plasma interactions with strong electromagnetic fields inside complex device structures. One of the first tasks for users of PIC codes is to precisely define the 3D device geometry for their simulation. To simplify this task for users of NRL's Neptune code, we have created a new approach to import geometric models from commonly used Computer-Aided Design (CAD) tools.

There are two primary approaches commonly used to define 3D geometry: (1) CAD modeling tools, and (2) Constructive Solid Geometry (CSG) methods. Conventional CAD tools represent and manipulate solid object surfaces using a boundary representation composed of 2D surface patches. CSG methods build complex geometry from a set of simple volumetric shapes (primitives, such as spheres or cylinders) composed using Boolean operations and geometric transformations.

In Neptune, we implement the CSG approach using a mathematical representation of shapes as implicit functions in 3D that produce positive values inside the structure, zero on the boundary and negative values outside. A function is then mapped onto the Cartesian simulation grid using an accurate "cut-cell"algorithm that determines intersections of the grid with the zero-valued surface-contour of the 3D function. A full scripting language is available to construct shapes/functions of arbitrary complexity using simple operations, however for sufficiently complex geometries this becomes a challenging programming exercise, in which case importing CAD models would be a more convenient approach.

We describe our new method, in which we transform the CAD model (using its surface triangulation) into Neptune's function representation. This enables the imported geometry to be used as a new primitive shape in the CSG model and further combined with other shapes, providing considerable flexibility to the user.

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