Approximate Volumes of Tremendous Constructive Solid Geometry Models

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Motivation

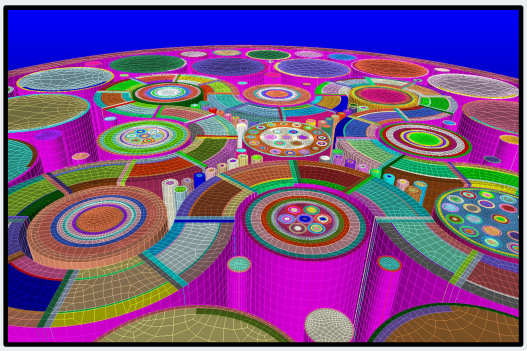
The input to the Monte Carlo algorithm for solving the neutron transport equation is a hierarchy of millions of CSG nodes. The volume of each node must be approximated accurately as volumes are used for calculating physical properties such as pressure and temperature.

Model Input

A reactor model consists of many interior disjoint, closed regions, called *components*, which are defined hierarchically to reduce memory and speed up physics calculation.

Each component C corresponds to a node N_C of the hierarchy. The node maintains a region $R(N_C)$ defined by a Boolean formula of implicit surfaces, a pointer to a single parent, and a list of children.

The component C is the set of points in the intersection of $R(N_C)$ with its ancestor's regions and its children's regions removed. We seek to compute the volume of each component of the model.



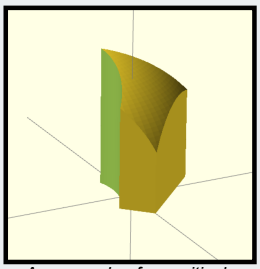
A rendering of the INL Advanced Test Reactor
Image from Idaho National Laboratory, license CC 2.0

Algorithmic Approach

1) Starting at the root, we build the approximate boundary of each component. Only surfaces that appear on the parent's boundary are propagated to the children.

2) We split each face such that it either bounds the component from above or below.

3) We approximate each component's volume by summing signed volumes bounded between faces and a reference plane. Volumes of faces bounding the component from above have pos. sign, and below have neg. sign.



An example of a positively signed volume below a spherical surface patch.

Simple 2D Illustration

Layers top to Bottom:

1. *The component C whose volume we are computing.*
2. *Split faces so they bound C either from above or below.*
3. *Compute volume of lower bounding faces to ref plane.*
4. *Compute volume of upper bounding faces to ref plane.*
5. *Their difference is the volume of C.*