Overview of Geometry Representation in Monte Carlo Codes

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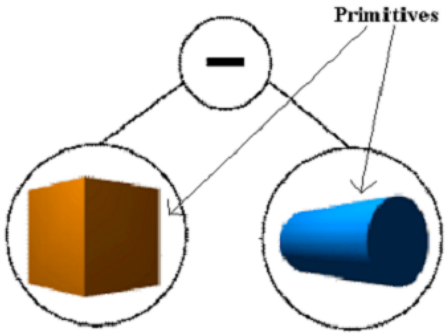
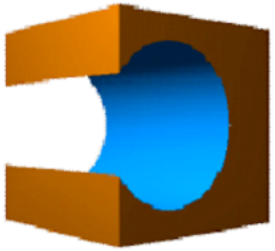
Problem Setup: Engineering designs CG vs. CAD

Combinatorial Geometry (CG)



CG Subtraction



The Resulting Solid

- Engineering designs are not typically created in this format
- No general automatic translation from CAD to CG yet exists
- Problem setup is difficult: Creation of CG models with engineering detail is labor intensive

CAD Geometry

- Engineering designs are readily available in this format
- Problem setup is expedited: New and iterated designs are readily created.
- CAD designers may not understand the need for clean geometry (without overlaps and gaps)

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Monte Carlo Radiation Transport Utilizing CAD models

- **Design to Analysis Problem: Utilize Engineering CAD models**
  - **Solutions are related to visualization techniques**
  - **Pertinent for linear transport (geometry does not change under transport)**

- **Approach #1: Create CG model**
  - **Manually (to be avoided)**
  - **Automatic translation to CG under development**

    (for LANL's MCNP)
    - » **Manson (Raytheon) : Analytical surfaces extracted from CAD (STEP) format by TopAct code**
    - » **Tsige-Tamirat (Karlsruhe): Algorithm to create semi-algebraic representations**
  - **Automatic translation to mesh, which is represented in CG**
    - » **Unstructured mesh as opposed to regular (e.g. voxels)**

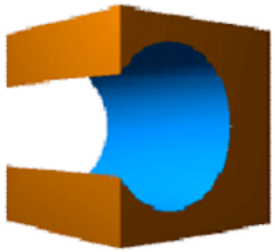
Monte Carlo Radiation Transport Utilizing CAD models

- Approach #2: Modify the Monte Carlo code to understand new formats
  - » CAD geometry
  - » Facetted geometry
    - Used for visualization
    - Jordan's NOVICE code (EMP consultants) transports on facet representations
  - – Tautges (SNL) has investigated similar approach for MCNP
  - – We will discuss utilization of CAD and facetted models by Sandia's electron / photon Monte Carlo code, ITS
    - » Interfaced with any geometry kernel that supports ray shooting queries

Efficiency Issues
CG vs. CAD

CG

- Performs ray intersection with infinite surfaces
- Then performs simple min/max logic (due to Boolean construction)
- All space is defined
- Computationally very efficient



CG Model
- 1 Code zone
- 2 Primitives
- 9 Surfaces

CAD Model
- 1 Lump
- 1 Shell
- 8 Faces
- 8 Loops
- 36 Coedges
- 18 Edges
- 12 Vertices

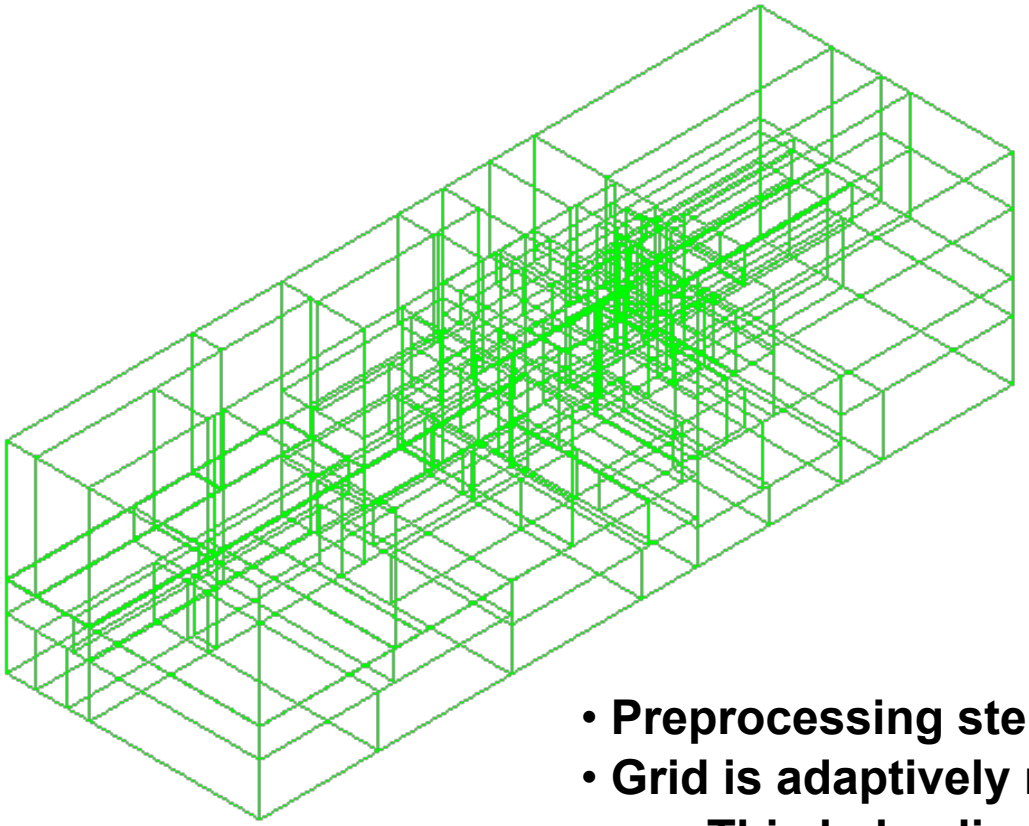
B-rep CAD description

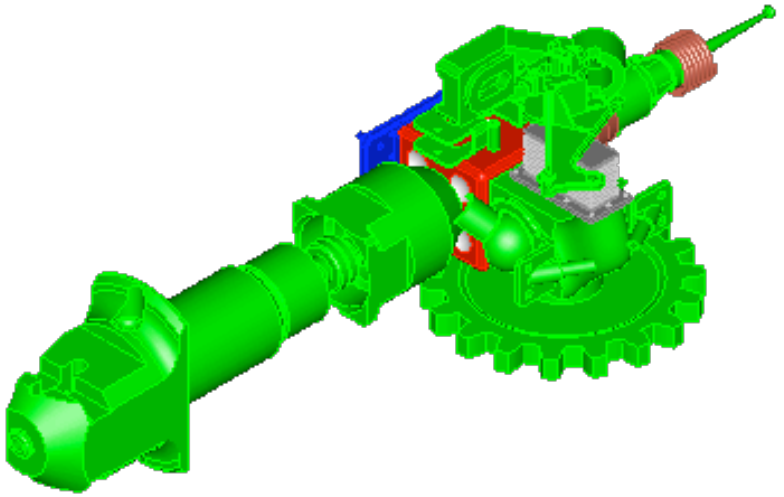
CAD Geometry

- Performs ray intersection with infinite surfaces
- Then performs point-in-face calculation (since a face is a trimmed surface), then min/max
- Needs special logic for transport in undefined space
- Can be 1-2 orders of magnitude slower than CG
- Splines can increase run-times by more orders of magnitude

Typical CAD model:
~ 13,000 Faces
~ 25,000 Edges
~ 19,000 Vertices

Efficiency Grid expedites CAD-based transport



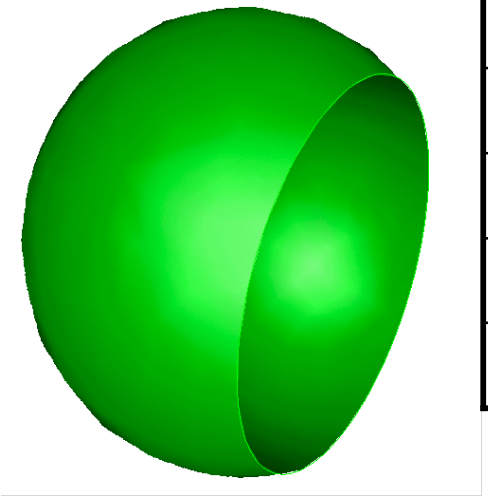


- Preprocessing step to create an efficiency grid
- Grid is adaptively refined.
  - This helps limit and order the surfaces to be interrogated based on the position and direction of a particle.

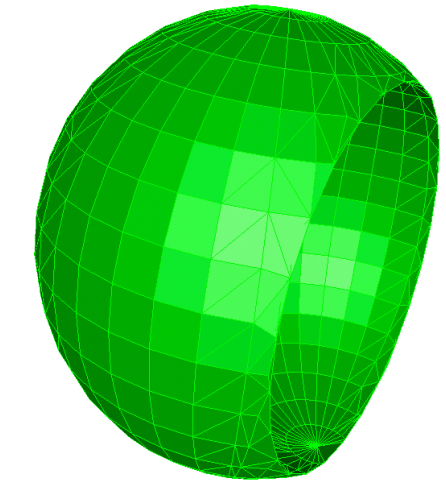
Grid is traversed with KD-Tree mapping

Faceted Geometry (Bowl): Surface mesh

- Transport on Splines can be sped up by faceting



	Time (ms/history)
CG	0.007
Facets	.22
CAD	.64
Splines	64.3



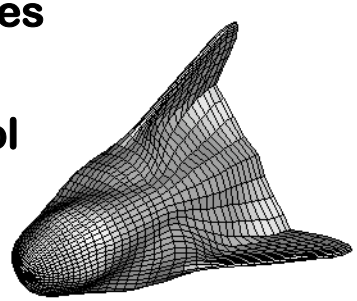
- Speed for facetted geometry varies, in this case ~1600 facets were used

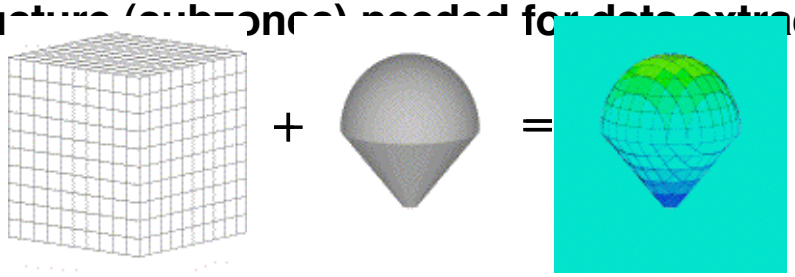
Exploring Geometry Alternatives

More automated

Less automated

- CAD geometry
  - Requires linking ITS with commercial CAD libraries
- CAD with Faceting of spline surfaces
  - CUBIT meshing software (SNL) allows this control
  - Improves efficiency
- Faceting of entire geometry
  - Essentially a surface mesh
  - Removes need to port CAD commercial
  - CUBIT meshing software used (automated for visualization)
- Meshing the entire geometry
  - On parallel machines, spatial decomposition may be needed
  - Other new logic may be needed
  - Mesh-like structure (subzone) needed for data extraction in regions





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Summary / Future Work

- Variety of geometry modeling approaches
- Methods may be used in combination in the same geometry
  - Currently available in ITS:
    - » Hybrid CAD-CG
    - » Hybrid CAD-CG-Facets
  - Under development: Hybrid CAD-CG-Facets-Mesh
- Investigate errors introduced by discreteness of faceted and mesh geometry models