SAND2004-2642P

Tracking Particles Through Faceted Geometries in Monte Carlo Radiation Transport Simulations

August 5th, 2003

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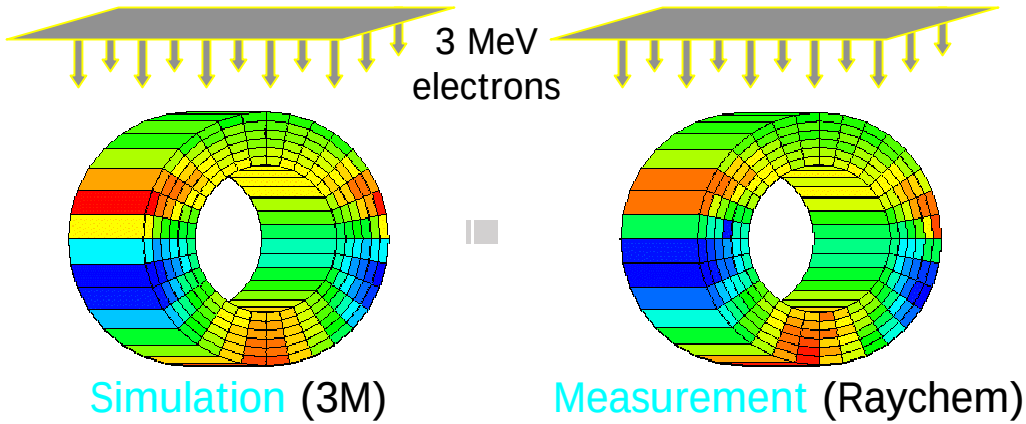
Integrated Tiger Series(ITS)

ITS (Integrated Tiger Series) permits a state-of-the-art Monte Carlo solution of linear time-integrated coupled electron/photon radiation transport problems with or without the presence of macroscopic electric and magnetic fields of arbitrary spatial dependence

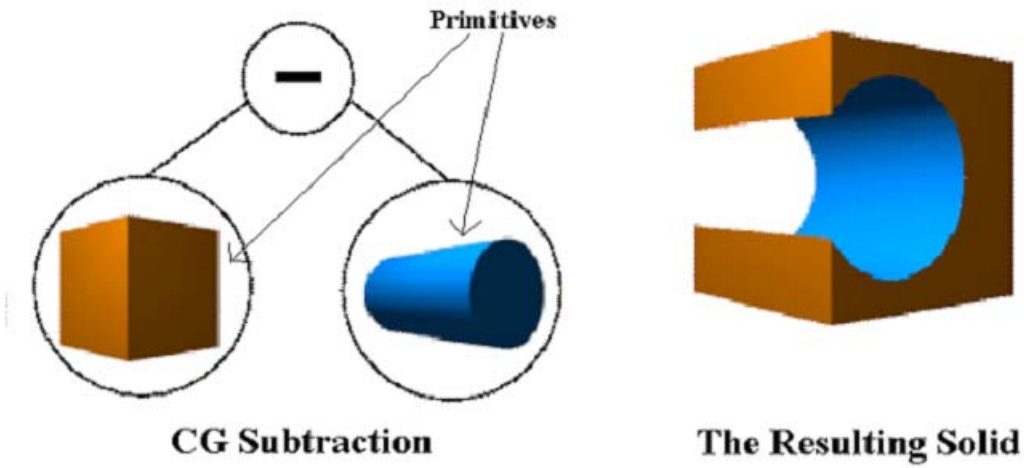
How is that useful?

ITS allows designers to predict product performance in radiation environments



ITS Combinatorial Geometry(CG)

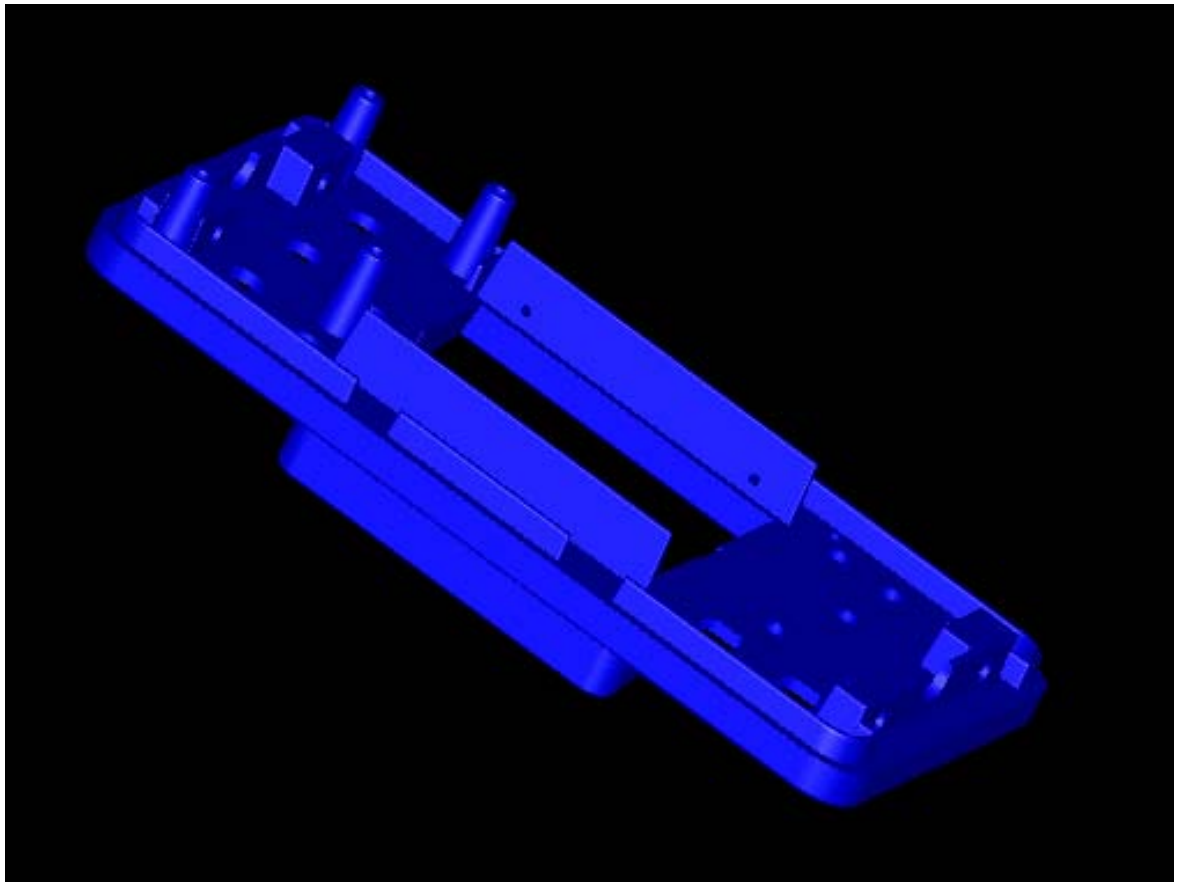
- In a CG representation, each model is built from Boolean combinations of primitives
- These combinations form a tree of primitives and set operations such as unions, intersections and subtractions



ITS CAD

- Allows ITS to run on models from modern CAD systems (Pro Engineer, Solidworks, etc..)
- Uses boundary representation topology with nonuniform rational b-splines (NURBS) surfaces to interrogate and represent geometry
- Based upon Spatial Software's ACIS engine

Boundary Representation Example



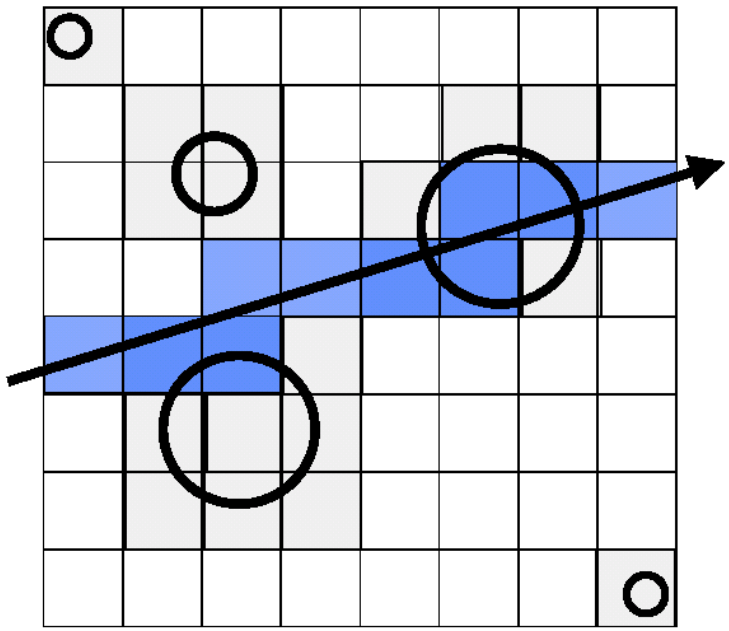
What's the problem?

Boundary representations are:

- **Slow to query (orders of magnitude slower)**
- **Quickly outdated due to proprietary formats**
- **Hard to translate between CAD systems**

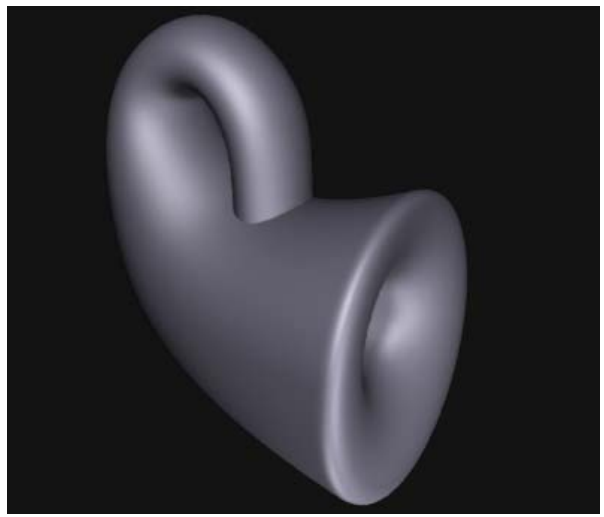
Why is ITS CAD so slow?

- Uses a regularized grid that does not:
  - adapt to input geometry
  - take into consideration level of detail



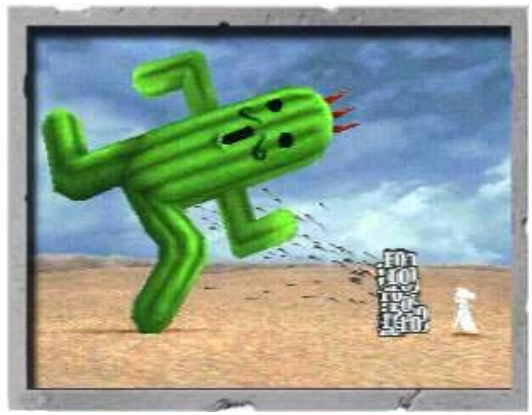
Why is ITS CAD so slow?

- Ray intersections involve evaluating the basis function in the splines equation



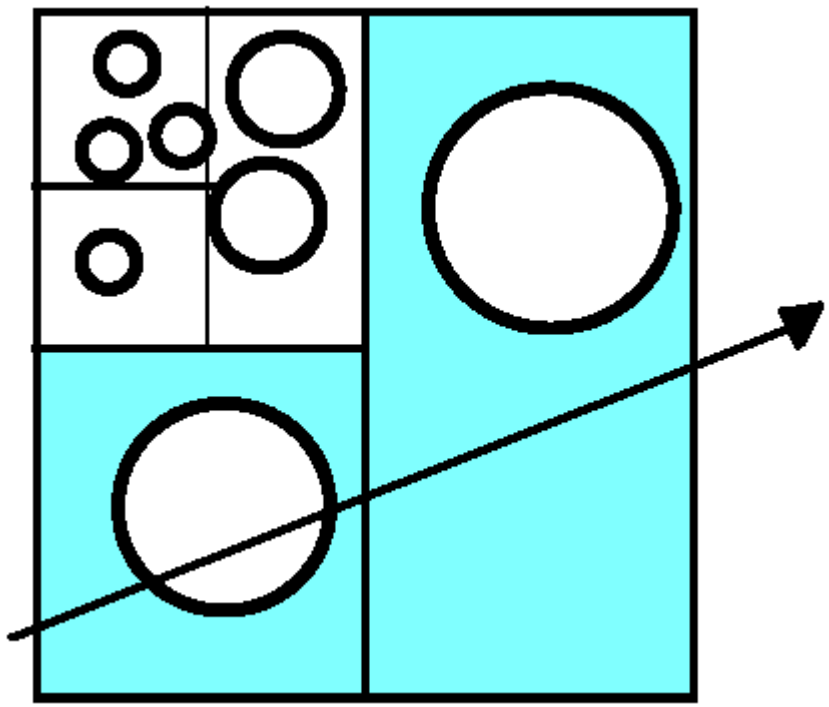
$$\mathbf{S}(\mathrm{u},\mathrm{v}) = \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \sum_{i=1}^{n} \sum_{j=1}^{m} N_i^k(u) N_j^l(v) \mathbf{P}_{i,j}$$

3-D Game Engines are the answer!



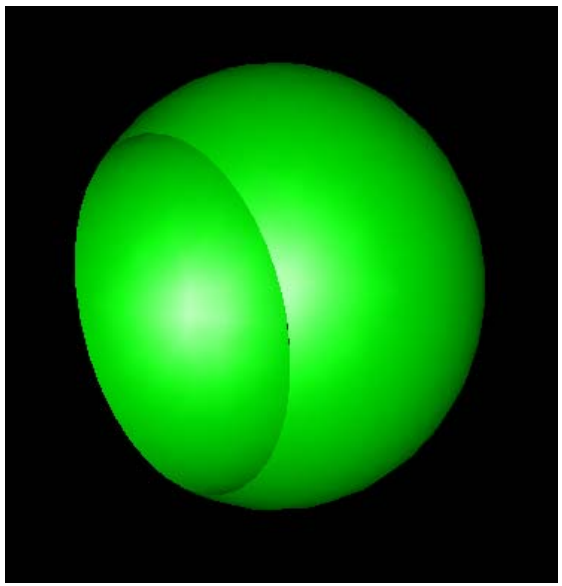
BSP Trees

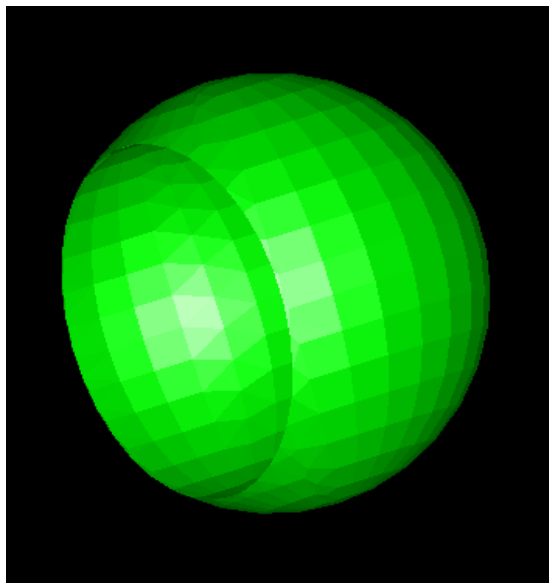
- Adapt to different geometries and level of detail
- Define maximum number of objects in each cell
- O(log N) ray evaluation



Faceted Geometries

- Game makers have been optimizing ray shooting algorithms for years
- All modern processors have special instructions to support this evaluation (3D-Now!, MMX)





BSP Trees and Facets Working Together

- The Quake3 engine developed by ID software combines faceted geometries and BSP trees to make what it considered the best faceting engine in the world
- BSP trees make up the game levels, in essence ITS is moving electrons and photons through a game world

Other Advantages

- Faceted geometries are represented in the Stereo Lithographic Format(STL) which is an industry standard
- The format does not change and is a simple collection of vertices and edges
- All major CAD drawing systems can output in an STL format
- Industry standard for rapid prototyping

Preliminary Results for Bahamut Engine

- Ray intersection tests on facets are 200 times faster than on spline surfaces
- Preprocessing time is 9 times faster for BSP tree than current uniform grid

Thank You

- Manager: Len Lorence
- Technical Advisors: Ron Kensek, Brian Franke
- ACIS Advisor: Paul Wolfenbarger
- All of the ITS Team
- All of department 15341