Title: MCNP6 Hybrid Geometry: Overview (U)

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MCNP6 Hybrid Geometry

Overview
This presentation provides an overview of the new hybrid geometry capability in MCNP6. The modeling paradigm, some implementation, and user requirements are discussed. The new MCNP input cards are presented. A simple example is shown to illustrate some of the relevant ABAQUS® features. Recent accomplishments and near term goals are mentioned.
This Talk

Outline

- Overview of the capability
- A quick view of the new MCNP Input Cards
- Concrete cylinder example / sample results from ABAQUS
- Recent accomplishments
- Near term goals
Capability Overview
Objectives of these next slides:

- Provide the user with a basic understanding of
  - the modeling paradigm used in this hybrid approach
  - some implementation & user requirements
New Capability For MCNP6

Embedded mesh

- Mesh geometry co-exists with MCNP cell-based geometry.
  - read from separate input file
- Implemented as a universe.
- Ultimately, "many" instances of the same mesh or instances of "several" different mesh.
Some Geometry Requirements

Irregular mesh body

Tracking considerations:

1. Outside hitting
2. Outside missing
3. Inside
4. Leaving cleanly
5. Re-entrant

mesh universe / fill cell
New Capability For MCNP6

Current Implementation

Unstructured mesh with 4-, 5-, and 6-sided elements generated by the ABAQUS® finite element program. Surfaces may be bilinear.

Currently, no mid-point nodes permitted.
Example Geometry

Osaka Aluminum Sphere
Benchmark Problem
Background: Constructing A Mesh Geometry

Created with ABAQUS

- The final model is an "assembly" constructed with "instances" of "parts"

- Each "part" can consist of
  - a single segment of one material
  - multiple segments of different materials

- Each "part" can be meshed independently with different element types

- MCNP converts the assembly into a global mesh model for its use
Background: Constructing A Mesh Geometry

- How to map the material descriptions to the mesh?
- How to take advantage of MCNP’s cell-base machinery?
Background: Constructing A Mesh Geometry

Created with ABAQUS

- Each part must contain three element sets (elsets) of data for:
  - materials
  - statistics
    - Can not encompass multiple materials
    - Used for cell-based tallies
  - exterior surfaces
Pseudo-Cells

- Each part--material--statistic region is automatically mapped to a pseudo-cell.
- The numbering of the pseudo-cells starts at 1 and occur in the order in which ABAQUS instances the parts to construct the assembly and the order of the statistical regions within the part.
- There must be one MCNP cell for each mesh pseudo-cell.
- The MCNP cell must contain the correct material definition for the pseudo-cell.
Background: Constructing A Mesh Geometry

Pseudo-Cell Example

1 part with 2 materials

3 defined & 2 undefined statistical regions

5 pseudo-cells (always consecutively numbered from 1)
Modeling Considerations

Contact Pair

- Parts/Instances sharing a (flat) surface but not nodes.
- Parts/Instances trying to share a curved surface, resulting in overlaps and gaps.
Modeling Considerations

4 Parts

3 Contact Pair Surfaces

Redundant nodes on each contact pair surface
Modeling Considerations

Two Parts On A Curved Surface
Modeling Considerations

Gaps & Overlaps
Some Implementation Drivers

Modeling Considerations or "Style" Dictate Tracking Implementation

- One part model with possibly many material sections
  - quickest when tracking from element to element (use nearest neighbor search)

- Multi-part model with contact pairs
  - more work required to find the next element on the other side of the contact pair surface

- Multi-part model with overlaps and gaps / re-entrant surfaces
  - most work required; may need to look at all elements

User has control over the model
More Implementation Drivers

Additional Requirements

- Path length estimates of flux, energy deposition, and/or fission energy by mesh element
  - Referred to as "elemental edits"
  - NO statistical uncertainties on results
  - Results output (including mesh geometry) in a special file
  - Dictates tracking implementation
    - Path length estimation (like MCNP) produces result in each mesh element through which the particle tracks.
    - Surface-to-surface "fast" tracking is not efficient in producing results in the mesh, but is desirable for transport speed up where edits aren't needed.
Current Restrictions

- Neutral particles only
- Charged particle tracking to be added later
Input Cards
**Embedded Mesh Universe**

- Geometry mesh are embedded as the lowest level universe.

**Cell card requirements:**
- At least one cell card with an embedded universe parameter "embu" along with the "u" parameter is needed to embed the mesh universe.
- "embu" value must coordinate with the number on the "embed" data card.
- One cell card with "embu" parameter for each mesh "pseudo-cell".
- All cell cards with the "embu" parameter must appear first.
- Immediately following the "embu" parameter cards must be a cell card with the "fill" parameter.

```
c  ***  Cell cards  ***
11  2  -7.8240  -8  embu=1  u=2
12  1  -1.2230  -8  embu=1  u=2
13  2  -7.8240  -8  embu=1  u=2
10  3  -0.0012  -8  embu=1  u=2
20  3  -0.0012  -8  fill=2
  6  3  -0.0012  -8  -7
  7  0  -0.0012  -7
```
Embedded Mesh Data Cards

Embedded Mesh Control Card

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMBEDn</td>
<td>embedded mesh universe number</td>
</tr>
<tr>
<td>n</td>
<td>(only one card currently permitted)</td>
</tr>
<tr>
<td>meshgeo</td>
<td>mesh geometry type</td>
</tr>
<tr>
<td>Current permitted values: abaqus</td>
<td></td>
</tr>
<tr>
<td>mgeo1n</td>
<td>mesh input file name</td>
</tr>
<tr>
<td>meeout</td>
<td>elemental edits output file name</td>
</tr>
<tr>
<td>meein</td>
<td>elemental edits input file name</td>
</tr>
<tr>
<td>(valid only in continuation runs)</td>
<td></td>
</tr>
<tr>
<td>length</td>
<td>conversion factor to centimeters for all mesh dimensions in input and output</td>
</tr>
</tbody>
</table>
Embedded Mesh Data Cards

Elemental Edits Control Card

EMBEEEn:<pl> embed= length= energy= time=

n

elemental edit number ending in 4, 6, or 7 follows tally convention
current maximum of 4 cards

<pl>

particle designator from particle list
current valid entries: n or p

embed

embedded mesh universe number
must correspond to a valid embed card #

energy

conversion factor from MeV/gm or jerks/gm
for all energy related output

time

conversion factor from shakes for all time
related output
Embedded Mesh Data Cards

Elemental Edit Energy Bins & Multipliers

\[ \text{EMBEBn} \quad B_1 \quad B_2 \quad \ldots \quad B_k \]

\( n \) elemental edit number; 0 is not valid.

\( B_i \) monotonically increasing upper energy of the \( i \)‘th bin.

\[ \text{EMBEMn} \quad M_1 \quad M_2 \quad \ldots \quad M_k \]

\( n \) elemental edit number; 0 is not valid.

\( M_i \) monotonically increasing upper energy of the \( i \)‘th bin.
Embedded Mesh Data Cards

Elemental Edit Time Bins & Multipliers

**EMBTBn** \( B_1 \ B_2 \ ... \ B_k \)

- \( n \) elemental edit number; 0 is not valid.
- \( B_i \) monotonically increasing upper time of the \( i^{th} \) bin. values in units of shakes (1 shake = \( 10^{-8} \) s)

**EMBTMn** \( M_1 \ M_2 \ ... \ M_k \)

- \( n \) elemental edit number; 0 is not valid.
- \( M_i \) monotonically increasing upper energy of the \( i^{th} \) bin.
Concrete Cylinder Example
Concrete Cylinder Geometry

R = 100 cm
H = 80 cm

Source:
2 MeV neutrons;
mono-directional
along Z-Axis
Concrete Cylinder: 1 Part / 2 Mesh Zones
Total Energy Deposition: 3-D View With $\frac{3}{4}$ Geometry
Total Energy Deposition: 3-D View With Half Geometry
Total Energy Deposition: 2-D View

Particle type 1: ENERGY_6, energy bin 1
(Avg: 75%)

- +2.5e-04
- +3.107e-04
- +1.19e-04
- +9.49e-05
- +5.5e-06
- +2.29e-06
- +1.5e-06
- 19.305e-07
- +5.199e-07
- +1.389e-06
- +1.511e-06
- +6.373e-07
- +3.300e-07
- +8.300e+00

Los Alamos National Laboratory
UNCLASSIFIED
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA
Concrete Cylinder: total neutron flux movie

UNCLASSIFIED

Slide 34
Concrete Cylinder: total neutron flux movie

Los Alamos National Laboratory
EST. 1943
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA
Concrete Cylinder With Penetration (5 cm radius)
Accomplishments
Accomplishments

Important Development Milestones To Date:

1. Methods for “working with” unstructured mesh researched and programmed.
   - Implemented with planar and bilinear surfaces for intersection & containment
   - skd-tree for searching mesh
   - Contact pairs, re-entrant particles, gaps / overlaps

2. ABAQUS input parser

3. Mesh edit results file & visualization

4. Serial, omp, and mpi versions of the code are being tested.

5. Presented some preliminary results at the ANS RPSD08 meeting
Near Term Goals
Near Term Goals

Next 6 Months

1. Continue testing & "bug" fixing
2. Resolve integration issues
3. Present user interface to MCNP Change Control Board
4. Implement surface-to-surface fast tracking
5. Implement quadratic surfaces
6. Technical society presentations
7. Documentation
8. Interest others in using these tools or fund further development