FZ2MC: A Tool for Monte Carlo Transport Code Geometry Manipulation

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Introduction and Motivation

- Many Monte Carlo transport codes employ a combinatorial geometry (CG) representation of the three-dimensional (3-D) configuration space [1],[2],[3],[4].
- While this technique for defining complex geometries is quite powerful, it can also be time consuming for the code user:

  ➔ The time required to manually produce an accurate, validated CG representation of a complex problem can range from weeks to months

- In the interest of ease of problem setup, many users routinely make approximations which simplify the problem geometry. These approximations can limit the accuracy of a Monte Carlo transport simulation.
- Common errors that arise from manual generation of problem geometries (gaps between cells and cell overlaps) can also lead to inaccurate particle tracking.
- As a result, the process of creating the problem geometry is often the limiting step in the formulation of a Monte Carlo transport simulation model.
- A tool that assists the user in creating and validating CG models is long overdue!

FZ2MC: A Tool for Combinatorial Geometry Manipulation

- In an effort to simplify the process of producing a Monte Carlo CG model, our team has developed a tool called ***FZ2MC***, which enables the user to create, modify and validate a Monte Carlo geometry model.
- This tool is a custom extension of the professional 3-D solid / surface geometry modeler ***Form-Z***, a product of AutoDesSys, Inc. [5]

- The name ***FZ2MC*** is an acronym for '*Form-Z to Monte Carlo*'.
- ***Form-Z*** is a collection of modeling and drafting tools that are incorporated into an intuitive point-and-click graphical user interface (GUI). The ***Form-Z RenderZone Plus*** version of the tool includes professional animation and rendering capabilities.
- ***Form-Z*** has been used by a diverse 3-D design community for more than 16 years, with a significant numbers of users in the architectural, product development, and motion picture industries.

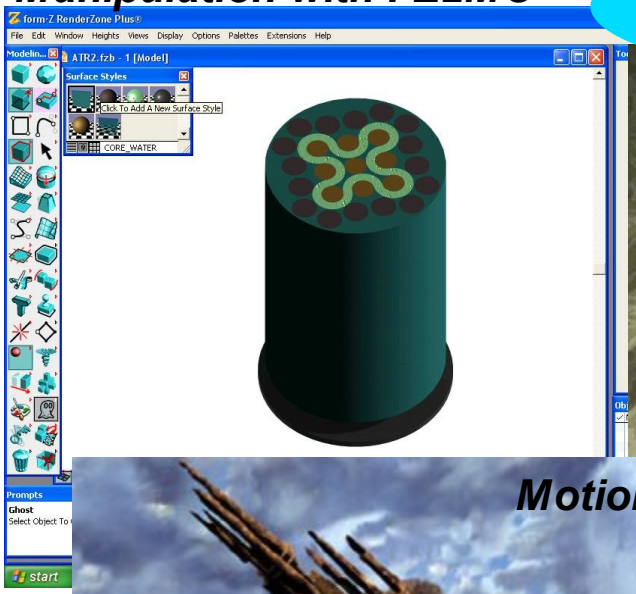
The Form-Z Solid Geometry Modeling Tool

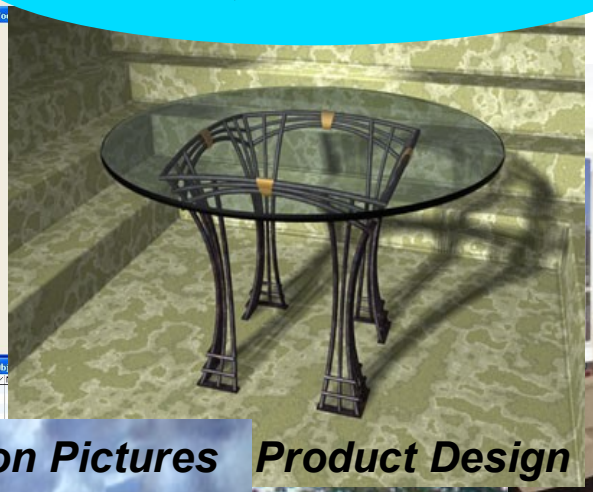
Examples of Modeling and Rendering Capabilities

Monte Carlo CG Manipulation with FZ2MC

www.formz.com

form·Z 6.6 RenderZone PLUS





Product Design

Interior Design

Motion Pictures

Architecture

Our Approach to Rapid Tool Development

- An important feature of ***Form-Z*** is the included software development kit (SDK) that allows the user to write custom scripts and plug-ins in C / C++ via calls to native application programmer interface (API) functions.
- The provided API functions allow the user to create custom object (*cell*) attributes, custom face (*surface*) attributes, as well as various tools and palettes.
- Our team has used this feature of ***Form-Z*** to produce a suite of generic plug-ins, in addition to plug-ins that both export and import the geometry input syntax of several Monte Carlo transport codes.
- Currently, ***FZ2MC*** provides (rudimentary) export / import capabilities for the following LLNL Monte Carlo codes:
  - ➔ ***Mercury*** [4]
  - ➔ ***Cog*** [3]
  - ➔ ***Tart*** [2]
- Development of plug-ins for the ***MCNP*** [1] code is planned for the near future.

Our Approach to Rapid Tool Development *(continued)*

- The existing plug-ins only deal with a subset of the complete input syntax for the supported Monte Carlo codes:
  - ➔ Problem geometry section *(typically the most challenging and error prone portion of a Monte Carlo model)*
  - ➔ Material composition section
- Our development strategy is to extend the tools produced by experts in the fields of solid geometry modeling and visualization, thereby foregoing the development of a complete solid geometry modeling tool.
- This “don't reinvent the wheel” approach allows Monte Carlo code developers to concentrate solely on the aspects of geometry associated with their applications.
- Using this approach, the Monte Carlo transport community can leverage many years of Form-Z code development, and validation by other industries, while requiring only a modest coding investment.

Our Approach to Rapid Tool Development *(continued)*

- The import / export plug-ins for each supported Monte Carlo code comprise ~3K to ~5K lines of C / C++ code.
- While extension of the Form-Z tool permits rapid tool development, it is not open source software:
  - ➔ The nominal cost of ***Form-Z*** (***Form-Z RenderZone Plus***) is:
    - ~$1000 (~$1350) per-seat commercial site license
    - ~$525 (~$700) per-seat academic site license
- These costs are reasonable, when compared to the following costs:
  - ➔ Developing a custom solid geometry modeler
  - ➔ Analyst time spent developing and validating Monte Carlo transport models

Developing Combinatorial Geometry Models with FZ2MC

- In a typical FZ2MC usage scenario, the user defines both the 3-D geometry and material isotopic composition data for the model via the Form-Z GUI.
- Once this step is complete, the export plug-in is used to write a “proto” input file to disk which conforms to the input syntax of the supported Monte Carlo code:

  ➔ ***FZ2MC*** = '*Form-Z to Monte Carlo*'

- The import plug-in is used to parse an input file, and display the geometry and material composition data within the ***Form-Z*** GUI:

  ➔ ***FZ2MC*** is also ***MC2FZ*** = '*Monte Carlo to Form-Z*'

- Once the input file has been parsed and displayed, the user can:

  ➔ Modify and validate the geometry

  ➔ Modify the material composition

  ➔ Export the geometry into the input syntax of any supported Monte Carlo code

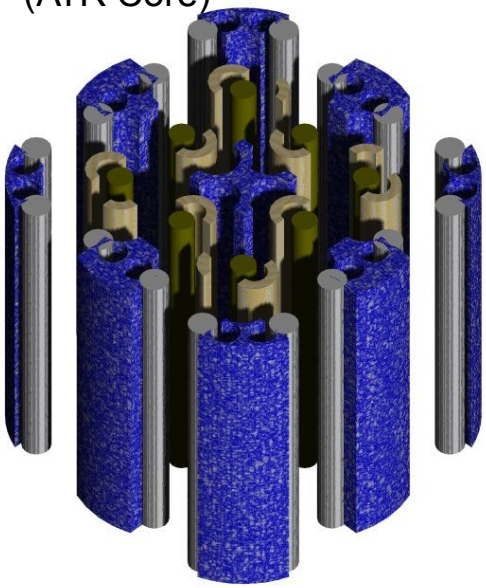
Features of the FZ2MC Tool

- The bi-directional import / export plug-ins provide a *translation* capability between the input syntax of the supported Monte Carlo codes.
- This translation feature of ***FZ2MC*** has proved to be useful for cross-code comparisons and "validation" of physics algorithms.
- Additional features of the ***Form-Z*** tool and the ***FZ2MC*** extension include:
  - ➔ *Material Assignment Check:* Verifies that all objects/cells have a corresponding assigned material
  - ➔ *Gap Check:* Determines which regions of space are enclosed by the problem boundaries are not located within any solid body
  - ➔ *Overlap Check:* Determines when two finite volumes / cells enclose the same region of configuration space,
  - ➔ *Exploded View:* An ability to *"explode"* objects, providing a detailed view of constituent parts of a complex geometry,
  - ➔ *Volume Calculation:* Automatically performed for cells

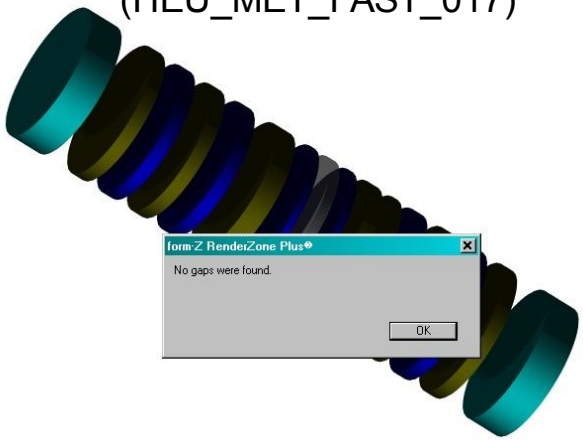
Features of the FZ2MC Tool *(continued)*

- Additional features of the ***FZ2MC*** tool *(continued):*
  - ➔ *Accurate Rendering:* Both volumes / cells and material surfaces can be rendered with custom texture attributes
  - ➔ *Material Definition:* Define materials with isotopic, elemental and custom material components.

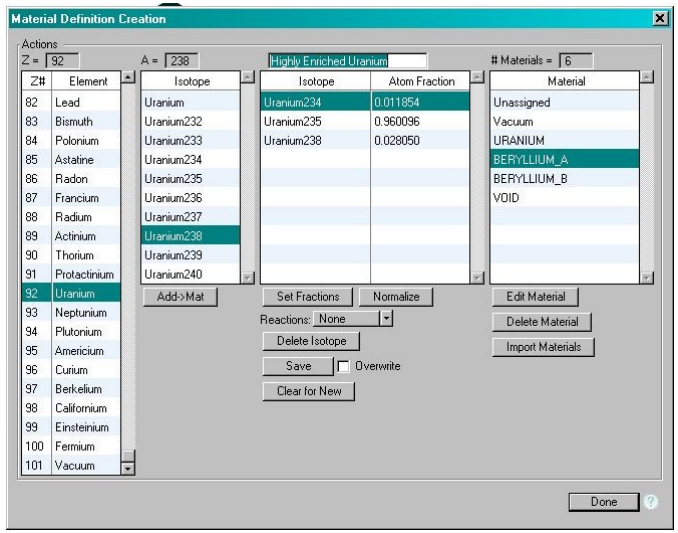
Exploded View
(ATR Core)



Exploded View and Gap Check
(HEU_MET_FAST_017)



Material Definition



The Future of the FZ2MC Tool

Collaborate with Our Team

- Our vision for the future of FZ2MC is to produce a “universal” tool for:
  - ➔ Creating and modifying 3-D CG models and material compositions
  - ➔ Validating 3-D CG models
  - ➔ Translating geometry, material composition and other input data between the input syntax of any supported codes
- Our team desires to work collaboratively with transport code teams at other institutions on the development of import / export plug-ins for use with their codes.
- The resulting translation capability can simplify the inter-comparison of results from, and aid in the validation of, the supported Monte Carlo codes.
- The goal of this effort is to create a web site and repository of ***FZ2MC*** plug-ins for ***Form-Z***:
  - ➔ Plug-ins can be freely downloaded
  - ➔ Software supporting additional Monte Carlo codes can be submitted

Summary and Conclusions

- Our team has developed a tool to aid the user of Monte Carlo transport codes in the creation and validation of combinatorial geometry models for use in transport simulations.
- The ***FZ2MC*** (*'Form-Z to Monte Carlo'*) tool:
  - ➔ Is an extension of the commercial solid geometry modeling tool ***Form-Z***
  - ➔ Permits users to create complex 3-D geometry and material composition input data via the ***Form-Z*** graphical user interface
- Additional features of ***FZ2MC*** allow the user to:
  - ➔ Validate combinatorial geometry models
  - ➔ Translate Monte Carlo geometry and material composition input data between codes for which a set of plug-ins have been developed
- It is our belief that this tool can benefit the entire Monte Carlo transport community. Our team desires collaboration with other code teams on the development of a repository of ***Form-Z*** plug-ins for ***FZ2MC*** that supports several Monte Carlo transport codes.

References

[1] L. J. Cox, et al., "*MCNP Version 5*", Los Alamos National Laboratory, Report LA-UR-02-1527 (2002).

[2] D. E. Cullen, "*TART 2005: A Coupled Neutron-Photon 3-D, Combinatorial-Geometry, Time-Dependent Monte Carlo Transport Code*", Lawrence Livermore National Laboratory, Report UCRL-SM-218009 (2002).

[3] R. M. Buck, et al., "*Cog User's Manual (Fifth Edition): A Multiparticle Monte Carlo Transport Code*", Lawrence Livermore National Laboratory, Report UCRL-TM-202590 (2002).

[4] R. J. Procassini, et al., "*Mercury User Guide (Version c.2)*", Lawrence Livermore National Laboratory, Report UCRL-TM-204296, Revision 1 (2008).

[5] "Form-Z Web Site", Auto*Des*Sys, Inc., http://www.formz.com (2008).

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