FZ2MC: A TOOL FOR MONTE CARLO TRANSPORT CODE GEOMETRY MANIPULATION

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ABSTRACT

The process of creating and validating combinatorial geometry representations of complex systems for use in Monte Carlo transport simulations can be both time consuming and error prone. To simplify this process, a tool has been developed which employs extensions of the ***Form-Z*** commercial solid modeling tool. The resultant ***FZ2MC*** (*'Form-Z to Monte Carlo'*) tool permits users to create, modify and validate Monte Carlo geometry and material composition input data. Plug-in modules that export this data to an input file, as well as parse data from existing input files, have been developed for several Monte Carlo codes. The ***FZ2MC*** tool is envisioned as a 'universal' tool for the manipulation of Monte Carlo geometry and material data. To this end, collaboration on the development of plug-in modules for additional Monte Carlo codes is desired.

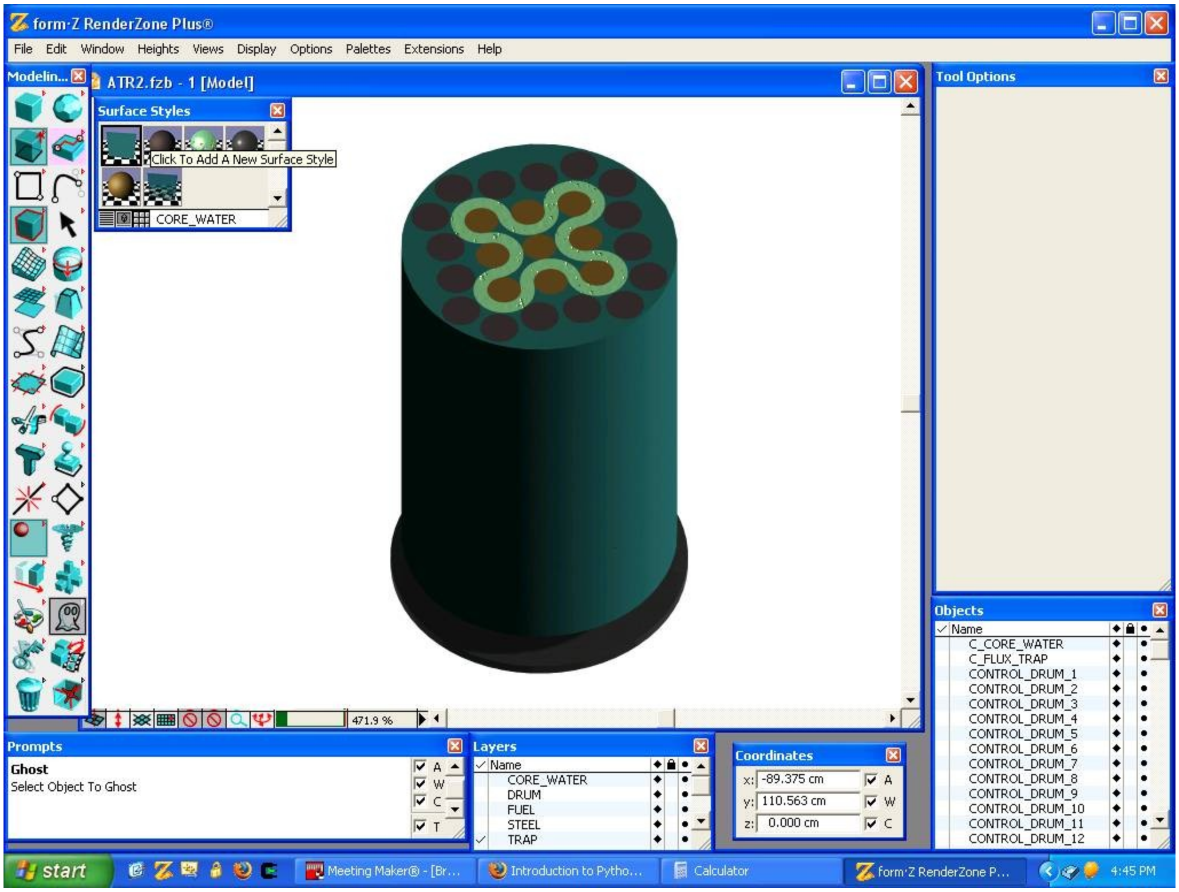
Key Words: Monte Carlo, combinatorial geometry, geometry creation and validation, ***Form-Z***

1. 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] This method subdivides the problem geometry into spatial volumes, or *cells*, which are defined by the logical aggregation of a set of bounding surfaces. These surfaces are typically analytic in nature, but can also be defined by splines or topographic data. While this technique for defining complex geometries is quite powerful, it can also be time consuming for the code user. In many cases, the time required to manually produce an accurate, validated CG representation of a complex problem can range from weeks to months. As a result, many users routinely make approximations which simplify the problem geometry, in the interest of ease of problem setup. These approximations can limit the accuracy of a Monte Carlo transport simulation. In addition, common errors that arise from manual generation of problem geometries, such as 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.

2. 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. An example of the photorealistic rendering capability provided in ***Form-Z RenderZone Plus*** is shown in Figure 1: a screen snapshot containing a rendered image of the Advanced Test Reactor (ATR)[6] within the ***Form-Z*** GUI.



Ghost
Select Object To Ghost

☑ A
☑ W
☑ C
☑ T

✓	Name	◆	🔒	●
	CORE_WATER	◆		●
	DRUM	◆		●
	FUEL	◆		●
	STEEL	◆		●
✓	TRAP	◆		●

x: -89.375 cm ☑ A
y: 110.563 cm ☑ W
z: 0.000 cm ☑ C

✓	Name	◆	🔒	●
	C_CORE_WATER	◆		●
	C_FLUX_TRAP	◆		●
	CONTROL_DRUM_1	◆		●
	CONTROL_DRUM_2	◆		●
	CONTROL_DRUM_3	◆		●
	CONTROL_DRUM_4	◆		●
	CONTROL_DRUM_5	◆		●
	CONTROL_DRUM_6	◆		●
	CONTROL_DRUM_7	◆		●
	CONTROL_DRUM_8	◆		●
	CONTROL_DRUM_9	◆		●
	CONTROL_DRUM_10	◆		●
	CONTROL_DRUM_11	◆		●
	CONTROL_DRUM_12	◆		●

Figure 1. A screen snapshot of the ATR geometry in the *FZ2MC* GUI, demonstrating the photorealistic rendering capabilities of the *Form-Z* 3-D modeling package.

2.1. Our Approach to Rapid Tool Development

An important feature of ***Form-Z*** is the software development kit (SDK) that is included with the package. This allows the user to write custom scripts and plug-ins via calls to native application programmer interface (API) functions. These code modules are written in a scripting/programming language that is an extension of ANSI C. 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 ***Mercury***[4], ***Cog***[3] and ***Tart***[2] Monte Carlo codes. Development of plug-ins for the ***MCNP***[1] code is planned for the near future. While the existing plug-ins only deal with a subset of the complete input syntax for these codes, namely the (a) geometry and (b) material composition sections, the geometry is typically the most challenging an error prone portion of a Monte Carlo model.

The development strategy that our team has employed extends 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. The import/export plug-ins for each supported Monte Carlo code are between 3K and 5K lines of C code. While extension of the ***Form-Z*** tool has permitted rapid tool development, one should bear in mind that it is *not* open source software. The nominal cost of ***Form-Z*** (***Form-Z RenderZone Plus***) is ~$1000 (~$1350) per-seat site license for commercial and ~$525 (~$700) for academic institutions. However, these costs are reasonable, when compared to the costs of (a) developing a custom solid geometry modeler, or (b) analysts developing and validating Monte Carlo transport models.

2.2. Developing Combinatorial Geometry Models with *FZ2MC*

A typical ***FZ2MC*** usage scenario has the user defining 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 employed to write a “proto” input file to disk. This file conforms to the input syntax of the supported Monte Carlo code, hence ***FZ2MC*** = '*Form-Z to Monte Carlo*'.

In contrast, the import plug-in is employed to parse an input file, and displays the geometry and material composition data within the ***Form-Z*** GUI. Thus, ***FZ2MC*** is also ***MC2FZ*** = '*Monte Carlo to Form-Z*'. Once the input file has been parsed and displayed, the user can (a) modify and validate the geometry or modify the material composition, and (b) export the geometry into the input syntax of either the donor code, or another Monte Carlo code for which a plug-in is available. As a result, these bi-directional plug-ins provide a *translation* capability between the input syntax of the supported Monte Carlo codes. This translation feature has proved to be useful for cross-code comparisons and “validation” of physics algorithms.

The ability to write custom plug-ins, such as the import/export features of ***FZ2MC,*** is one of many useful capabilities of ***Form-Z***. Additional features of the ***Form-Z*** tool and the ***FZ2MC*** extension include (a) a *material assignment check* which verifies that all objects/cells have a corresponding assigned material, (b) a *gap check* that determines which regions of space are enclosed by the problem boundaries are not located within any solid body, (c) an *overlap check* which determines when two finite volumes/cells enclose the same region of configuration space, (d) an ability to *"explode"* objects which provides a detailed view of constituent parts of a complex geometry, (e) a *volume calculation* for the cells is automatically performed, (f) *accurate rendering* of volumes/cells and material surfaces with custom texture attributes, and (g) a *material definition* capability which includes isotopic, elemental and custom material components.

2.3. The Future of the *FZ2MC* Tool

Our vision for the future of ***FZ2MC*** is to produce a "universal" tool for (a) creating and modifying 3-D geometry models and material compositions, (b) validating 3-D combinatorial geometry models, and (c) translating geometry, material composition and other input data between the input syntax of any supported codes. To accomplish this, our team desires to work collaboratively with transport code teams at other institutions on the development of import/export plug-ins for use with those codes. The resulting translation capability would greatly 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 repository of ***FZ2MC*** plug-ins for ***Form-Z***. This repository will be linked to a web site from which plug-ins can be freely downloaded, and to which software supporting additional Monte Carlo codes can be submitted.

3. SUMMARY AND CONCLUSIONS

In an effort to simplify the process of creating and validating combinatorial geometries for use in Monte Carlo transport simulations, our team has developed an extension to the commercial solid geometry modeling tool ***Form-Z***. The ***FZ2MC*** (*'Form-Z to Monte Carlo'*) tool permits users to create complex 3-D geometries and material compositions via a graphical user interface. Additional features of ***FZ2MC*** aid in the validation of combinatorial geometries, as well as translation of Monte Carlo geometry and material composition input data between codes for which a set of plug-ins have been developed. We believe that this tool can benefit the entire Monte Carlo transport community, and desire to collaborate with other code teams on the development of a repository of ***Form-Z*** plug-ins for ***FZ2MC*** that supports several Monte Carlo transport codes.

ACKNOWLEDGMENTS

This work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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