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Converting of McCARD Models to MCNP's for Visual Analysis

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1. Introduction

McCARD [1] is a continuous-energy particle transport calculation code using Monte Carlo (MC) Method, which is developed in Seoul National University (SNU). The code provides structured input processing and embedded python scripting which is quite useful for users to develop their own MC models efficiently. However, the absence of visualization tools in the McCARD code package has been a significant handicap for McCARD users, since the debugging of a complex geometry becomes extremely difficult task without visual images. Recently, a McCARD visualization program has been developed in SNU [2], but it has not been distributed to the McCARD user group yet.

Meanwhile, a simple procedure was suggested to generate visual images of McCARD models, and has been used for modeling complex experimental reactor geometries. Rather than developing a stand-alone application, existing graphic tools in the MCNP6 [3] code packages are utilized. By converting the McCARD input to MCNP's, one can obtain visual images from MCNP plotter or other 3rd party visualization tools. In this paper, the procedure is described with details, and the samples of visualized images are presented.

2. Method

The geometry in the both Monte Carlo code, McCARD and MCNP, are based on Constructive Solid Geometry (CSG). Because the cells in both codes consist of surrounding surfaces and their relations, conversion of McCARD models to MCNP models can be considered straight-forward. The cells and surfaces in McCARD have their own names, while they have IDs in MCNP, so the conversion process requires assigning proper IDs for cells and surfaces first. After assigning IDs, each cell in McCARD input can be converted to MCNP's line by line.

In McCARD, a cell can be filled by either homogeneous material or a pre-defined cell, called as Composition Cell (CCell). CCell is consist of group of cells and surrounding surfaces. MCNP's 'universe' plays the same role, so CCell can be converted to universe, by assigning universe ID to those cells that are members of CCell.

When CCell is directly converted to universe, the visualized image would show error in surfaces, at the boundary surfsce of a universe. MCNP assumes that the boundary of universe is either infinite or greater than the actual cell, so the boundary surface should be located outside of the actual cell. On the other hand, in McCARD, the actual cell and CCell should be the same, and the McCARD code rejects to reuse CCell if any of boundary surfaces are not found in CCell. Therefore, direct conversion of CCell to universe lead to surface errors in MCNP as plotted in Fig. 1.

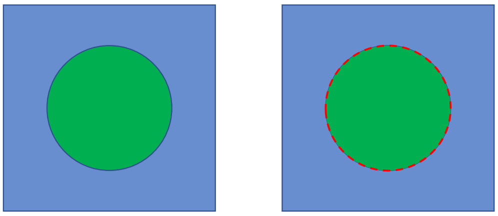

Fig. 1 Difference in geometry – CCell and TCEL in McCARD VS Universe and Fill in MCNP

In order to resolve this problem, the outer boundaries of CCell should be modified to have greater volume than the actual cells, such that boundary planes should be moved to outward and the radius of cylinder or sphere should be increased during the conversion procedure as plotted in Fig. 2. Without this treatment, a normal cell can appear to have errors with surfaces, and this hinders users to find abnormal cells in the geometry.

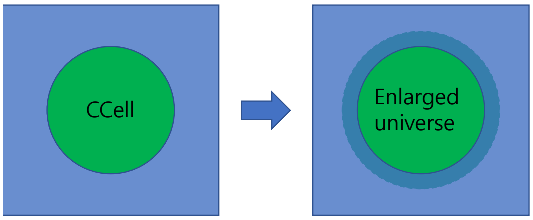

Fig. 2 Appropriate conversion of CCell to universe

Correct material information is not necessarily required for just plotting. Artificial materials with density of unity also works fine with the MCN plotter. However, the material information in McCARD models are converted to MCNP input forms for the complete conversion of models. The McCARD material information is provided after the geometry input decks, while summarized material information is required at the early stage in MCNP models to fill material density in the cell cards. Therefore, the density of material is obtained first by reading the McCARD material decks, and the obtained density is used for writing cell cards in MCNP.

In order to make the best use of the conversion, it is also strongly recommended to write captions for all the cells and surfaces. The geometric component in McCARD can be identified its name, so user can easily find cells and surfaces of interest. However, once they are converted to IDs in MCNP, it will be much difficult for users to find specific cells and surfaces in the model. In the visualized results, user can found only IDs of surfaces, cells, and materials. So, users have to know names of cell or surfaces instead of MCNP IDs to modify their original McCARD models. If the corresponding names are written in the converted MCNP input files, users can avoid the hassle to find proper names in the McCARD inputs.

In this work, a Perl script program was developed for converting McCARD models to MCNP's. The script code reads McCARD input first, and converts the cells, surfaces, and materials into MCNP input decks.

3. Examples of visualized images

As an example, a slice of a MCNP input which is converted from a McCARD model is given in Fig. 3. Even though the MCNP input is generated by a script, it is readable with the aids of proper captions.

```
c ================================
c CCell InnerAssm2D (u = 2)
c ================================
c Coolant
20001 7 2.4094e-2 +20001 +20002 +20003 +20004 +20005 +20006 &
   +20007 +20008 +20009 +20010 +20011 +20012 &
   +20013 +20014 +20015 +20016 +20017 +20018 &
   +20019 +20020 +20021 +20022 +20023 +20024 &
   +20025 +20026 +20027 +20028 +20029 +20030 &
   +20031 +20032 +20033 +20034 +20035 +20036 &
   +20037 +20038 +20039 +20040 +20041 +20042 &
   +20043 +20044 +20045 +20046 +20047 +20048 &
   +20049 +20050 +20051 +20052 +20053 +20054 &
   +20055 +20056 +20057 +20058 +20059 +20060 &
   +20061 +20062 -20063 +20064 -20065 +20066 &
   -20067 +20068 -20069 u=2 imp:n=1
c Fuel_001
20002 1 3.4592e-2 -20070 +20068 -20069 u=2 imp:n=1
c Clad_001
20003 6 8.2631e-2 +20070 -20001 +20068 -20069 u=2 imp:n=1
c Fuel_002
20004 1 3.4592e-2 -20071 +20068 -20069 u=2 imp:n=1
c Clad_002
```
Fig. 3 An MCNP input after conversion

Fig. 4 and 5 show visualized image of Chinese Experiment Fast Reactor (CEFR) Start-up test core [4], which has complicated geometries of many types of fuel and non-fuel sub-assemblies. Even though many CCells are used to build the core configuration in this McCARD model, surface error indications are not found in Fig. 5, which implies that all the CCells in the model were properly converted to universes in MCNP.

The conversion script has been used as a tool to debug the McCARD CEFR models, and we found that component-wise plotting can be very efficient when one is handling very large and complicated core. Because of limited performance of the plotter, handling a large core take significantly more time than a component model. Each CCell can be simply converted as a component by omitting the universe card at the CCell of interest, and skipping the structure section. An example can be found in Fig. 6 showing the fuel assembly for foil irradiation experiment in CEFR.

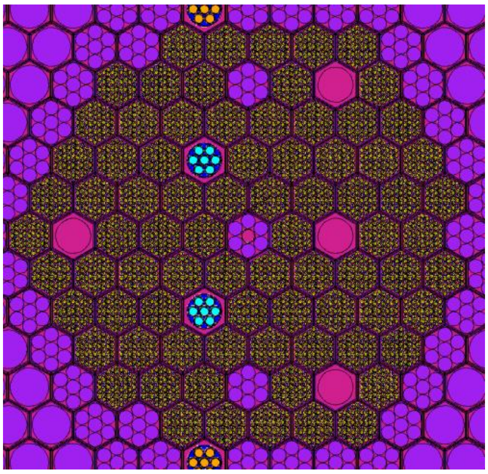
Fig. 4 The CEFR Start-up test reactor core

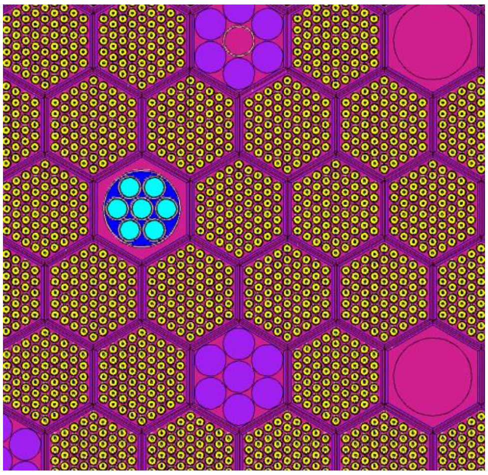
Fig. 5 A magnified image of the CEFR core

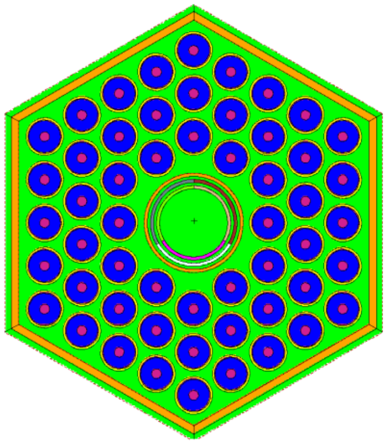
Fig. 6 Visualization of a CCell card – an fuel assembly for foil irradiation experiments in CEFR

Sometimes, the sub-assembly loading of core is required to be confirmed before the actual calculations. In this case, visualization of simple core configuration would be helpful instead of plotting the whole core. An MCNP model that contains only sub-assembly boundaries can be generated by filling the TCEL with artificial homogeneous material in the structure section. In this manner, user can check the core configuration efficiently. Fig. 7 shows an example of this approach, showing a typical SFR core layout.

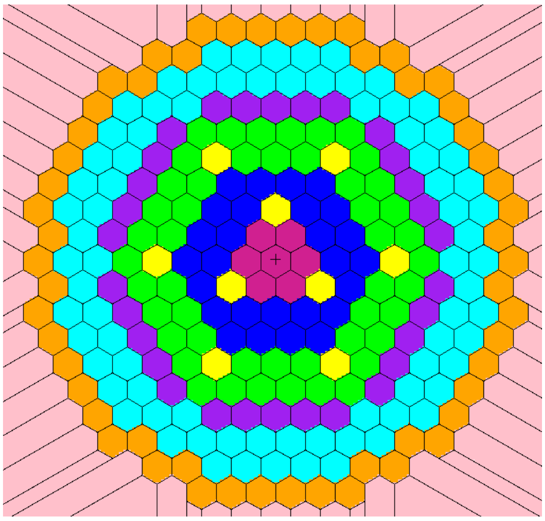

Fig. 7 An image of a typical SFR core layout

4. Conclusions

In order to obtain visualized images of McCARD models, an alternative approach was proposed and the results were presented. A Perl script program was developed for converting McCARD models to MCNP inputs, and visualized images were obtained by the MCNP plotter. The converting process was successful, and clear image of complicated McCARD models could be obtained easily. The suggested approach can be applied to all types of reactor problems, and it would be helpful for users to find geometric errors when they are developing their own McCARD models. Also, the converted MCNP models can be further utilized for code-to-code verification between the McCARD and MCNP codes.

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