# A Proposal on the Geometry Splitting Strategy to Enhance the Calculation Efficiency in Monte Carlo Simulation

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## 1. Introduction

Geometry splitting in Monte Carlo (MC) calculation is one of the most popular variance reduction techniques due to its simplicity, reliability and efficiency [1]. For the use of the geometry splitting, the user should determine locations of geometry splitting and assign the relative importance of each region. Generally, the splitting parameters are decided by the user's experience. However, in this process, the splitting parameters can ineffectively or erroneously be selected. In order to prevent it, there is a recommendation to help the user eliminate guesswork, which is to split the geometry evenly. And then, the importance is estimated by a few iterations for preserving population of particle penetrating each region [2]. However, evenly geometry splitting method can make the calculation inefficient due to the change in mean free path (MFP) of particles. As a preliminary study on the development of automatic geometry splitting method, in this study, how the geometry splitting strategy affects the calculation efficiency was analyzed [3].

## 2. Methods and Results

In deep penetration problems, to use the geometry splitting method, the shielding material is divided to the sub-regions with defining the arbitrary cells. The energy-dependent neutrons have a different mean free path in the shielding material as the neutron position due to the initial energy distribution and energy loss caused by the reaction with shielding material. As the results, the strategy, which is evenly divided to the sub-regions, can cause inefficiency on the variance reduction. To study how the geometry splitting strategy affects the calculation efficiency, the characteristics of the neutron distributions in a medium were first evaluated by applying initial source energy distributions. Then, benefits of figure of merit (FOM) according to the geometry splitting strategy were analyzed.

### *2.1 Overview of Proposed Strategy for Geometry Splitting*

For the analysis, a benchmark problem was assumed as shown in Figure 1. A shielding material is an iron having 30 cm thickness. The plane neutron sources are located at the front of the shielding material. The neutron energies for each case are set as shown in Table I.

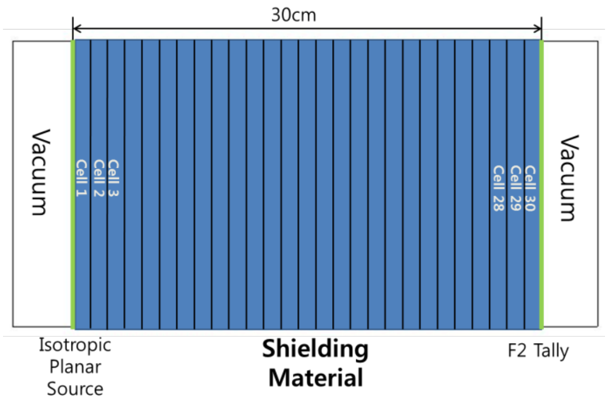



Fig.1. Overview of Shielding Benchmark Problem

Table I. Specification of Source Energy for Each Case

| Classification | Case 1 | Case 2 |
|---|---|---|
| High Energy | 10 MeV | 10 keV |
| Low Energy | 100 eV | 10 eV |

Case 1 and 2 have two discrete source energies, respectively. One is a high energy and another is lower energy for each case. Also, it is noted that the material cross sections for the neutrons having higher energy is much smaller than those of lower energies as shown in Table II. Hence, as the neutrons penetrate the shielding material, the population of the neutrons having lower energies is rapidly reduced. As the results, the average mean free path of the neutrons can be gradually increased as the cell approaches the detector.

Table II. Total Cross Sections in ENDF/B-VI Library

| $\sigma_t$ (barn) | Case 1 | Case 2 |
|---|---|---|
| High Energy | 3.1213 | 4.203 |
| Low Energy | 11.7060 | 12.1526 |
| Low E / High E | 3.7504 | 2.8914 |

To verify the phenomenon, Monte Carlo simulations were performed for the two cases. It was pursued by MCNPX 2.7.0 code with ENDF/B-VI cross section library [3]. After the simulation, the mean free paths for each case were obtained as shown in Figure 2. It is clearly notified that the mean free paths are changed for each location in the shielding material. To consider the change of the mean free path in mediums, a cell division method for the geometry splitting is proposed in this study. It is performed as the following procedure; (1) adjoint fluxes are calculated; (2) the attenuation boundary, which is evenly reduced of the neutron population, is calculated; (3) the cell is divided at each calculated boundary.

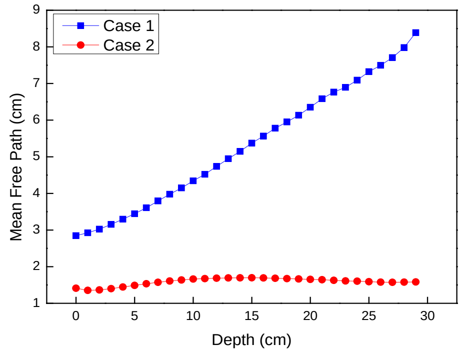



Fig. 2. Changes of Mean Free Paths as the Penetrated Depth in Case 1 and 2

*2.2 Analysis on the Calculation Efficiency for the Proposed Strategy*

To analyze the efficiency of the variance reduction method, FOM is often estimated. FOM is defined as Eq. (1).

$$FOM = \frac{1}{R^2 T} \tag{1}$$

where $R$ is relative error of a response and $T$ is computer time. For the evaluation of the calculation efficiency, at first, the neutron population of the benchmark problem as the penetration depth was evaluated as shown in Figure 3. Using the information, the geometry splitting with the proposed method was performed as shown in Figures 4 (a) and 5 (a). For the comparison, the geometry splitting method was applied with using the cells evenly divided. After the geometry splitting, the importance optimization was pursued as recommended in MCNP manual [4]. Finally, MCNP simulations were performed for each case.

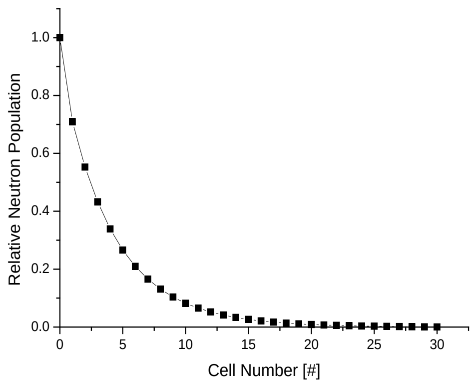
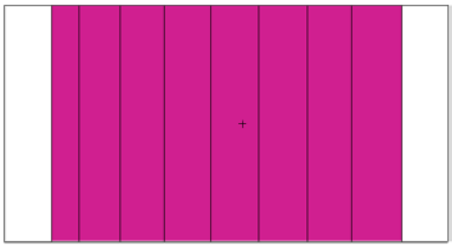
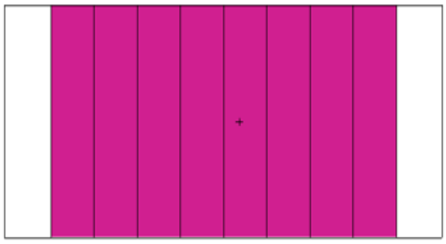



Fig.3. Relative Neutron Population as the Penetration Depth

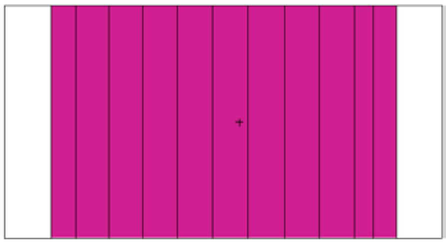


(a) Proposed Method

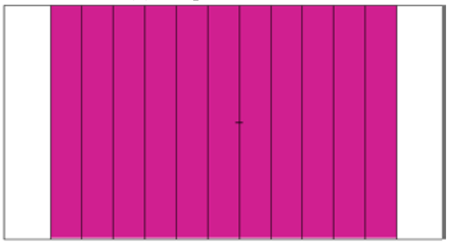


(b) MCNP Recommended Method

Fig.4. MCNP Modeling Results with Proposed Method and MCNP Recommended Method for Case I



(a) Proposed Method



(b) MCNP Recommended Method

Fig.5. MCNP Modeling Results with Proposed Method and MCNP Recommended Method for Case II

Table III shows the results of FOM with proposed method and MCNP recommended method. Analysis shows that the proposed method can increase the calculation efficiency from 0.81 % to 6.5 % in given cases.

Table III. The Results of FOM for Each Case

| Splitting Method | Case 1 | | Case 2 | |
|---|---|---|---|---|
| | Division* | FOM | Division* | FOM |
| Equivalently Divided | 8 | 30237 | 11 | 9537 |
| Proposed Method | | 31888 | | 10157 |
| Benefit (%) | | 5.46 | | 6.50 |
| Equivalently Divided | 4 | 30825 | 6 | 9663 |
| Proposed Method | | 32273 | | 9741 |
| Benefit (%) | | 4.70 | | 0.81 |

* Number of Cell Divisions for Geometry Splitting

## 3. Conclusions

In this study, a geometry splitting method was proposed to increase the calculation efficiency in Monte Carlo simulation. First, the analysis of the neutron distribution characteristics in a deep penetration problem was performed. Then, considering the neutron population distribution, a geometry splitting method was devised. Using the proposed method, the FOMs with benchmark problems were estimated and compared with the conventional geometry splitting strategy. The results show that the proposed method can considerably increase the calculation efficiency in using geometry splitting method. It is expected that the proposed method will contribute to optimizing the computational cost as well as reducing the human errors in Monte Carlo simulation.

## Acknowledgement

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