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McSEE Beta: A Visual-aided Monte Carlo Simulation Code for External Exposure

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1. Introduction

In 2016, the International Commission on Radiological Protection (ICRP) formulated Task Group (TG) 103 with the aim of developing Mesh-type Reference Computational Phantoms (MRCPs) in a high-quality tetrahedral-mesh format. The adult and pediatric MRCPs, which are the mesh counterparts of the existing voxel-type reference phantoms in ICRP *Publications 110* and *143,* were recently completed. The adult MRCPs were released through ICRP *Publication 145* [1] and the pediatric MRCPs [2] are soon to be released through ICRP *Publication 156*. The MRCPs show advantages over the ICRP-110 and -143 voxel phantoms mainly in defining very thin and small organs, e.g., the micrometer-scale target and/or source regions of alimentary and respiratory tract organs, eye lens, skin, and urinary bladder. Moreover, the flexibility of mesh format enables the MRCPs to be deformed to various poses or body sizes for individualized or stratified dosimetry.

Acknowledging the advantages of the MRCPs, the ICRP Task Group 112 (Emergency Dosimetry) decided to use the MRCPs to calculate reference dose coefficients (DCs) for emergency external exposure situations. However, it is practically impossible to establish reference DCs for all the possible exposure cases, due to the unlimited number of exposure scenarios. Therefore, TG112 decided to produce reference DCs for only some representative scenarios and for the other cases, a reference user-friendly dose calculation software will instead be released to be used by radiation workers or regulators to calculate case-specific DCs by themselves. For this purpose, McSEE, visual-aided Monte Carlo Simulation code for External Exposure, was started to be developed since 2021, providing the mesh phantom (including the MRCPs)-based dose calculation function. Recently, the beta version of McSEE was developed and in the present study, this McSEE (beta 1) will be introduced, including its overall design and features.

2. Overall design

McSEE is a mesh phantom-based visual-aided Monte Carlo dose calculation code. McSEE consists of two main modules: a graphic user interface (GUI) module and dose calculation module (see Figure 1). GUI module

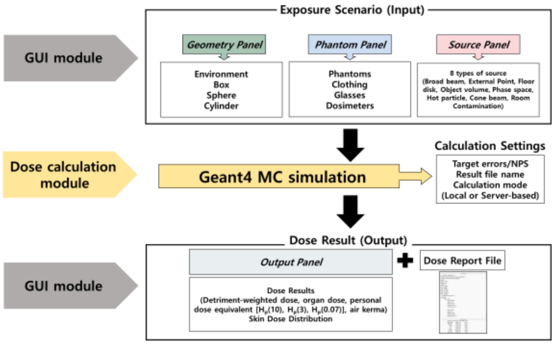

Figure 1. Overall design of McSEE

is a user-friendly workspace where the users can set exposure scenarios through geometry, phantom, and source panels and also view dose results through output panel. The users can see every entered input and calculated outputs through a visualization window in three dimensions. Dose calculation module runs Monte Carlo simulation using a pre-compiled C++ language-based Geant4 toolkit and calculates organ doses, detriment-weighted dose, personal dose equivalent, air kerma, and skin dose distribution on the mesh phantoms. Users can set local (personal computer) or server-based calculation mode depending on where to run the simulation. Dose calculation module is embedded in the GUI module, allowing users to interact only with the GUI module.

3. Features of McSEE GUI module

3.1. Geometry panel

Exposure geometries other than phantoms can be defined in the geometry panel. Box, sphere, and cylinder-shaped objects can be installed by entering parameters (e.g., length, thickness, angles, position, rotation, etc.) in the same format as Geant4 toolkit. Materials can be defined by entering the density and elemental compositions. For user convenience, the objects can be translated and rotated, even after the installation, while watching their position and rotation in the visualization window.

3.2. Phantom panel

Multiple phantoms, along with wearable items (i.e., clothing, dosimeters, and glasses), can be implemented in the phantom panel. Users can install phantoms by entering gender, age, height, weight, and pose. A phantom is selected and generated from 12 adult and pediatric MRCPs, 10 adult pose-dependent mesh phantoms, and 76 adult and pediatric body size-dependent mesh phantoms. Clothing can be installed by selecting the types of clothing or regions on the phantom and entering the thickness and materials. Dosimeters and glasses can be installed by clicking their position on the phantom and entering parameters (e.g., radius, thickness, separation distance from phantom surface, and materials). Like the geometry panel, the phantoms and wearable objects can be translated and rotated after installation.

3.3. Source panel

Various sources can be generated through source panel. McSEE allows eight types of sources: broad beam, external point, floor disk, object volume, phase space file, hot particle, cone beam, and room air contamination. Source positions and directions are shown in the visualization window (see Figure 2).

Figure 2. Eight types of sources in McSEE source panel

3.4. Output panel

Users can run Geant4 simulation using a personal computer or a server computer through dose calculation module. During simulation, real time dose results can be seen through the output panel (see Figure 3). Users can see organ doses with statistical relative errors through the number, bar, and graphs. In addition, skin dose distributions can be found in the visualization window. Current memory/thread usages, remaining time, and progress percentages are displayed in a status widget. Users can also stop the simulation using the Stop and Save button. After the simulation, all dose results and exposure scenarios are printed out as a text file. Users can reconstruct the exposure scenarios by loading this result text file.

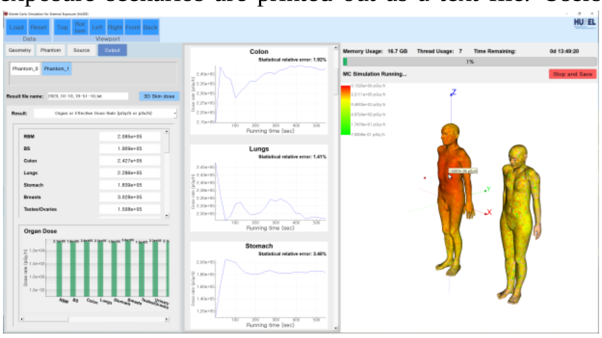

Figure 3. Dose results visualized in McSEE output panel

4. Preliminary benchmarking

A benchmarking against ICRP *Publication 145* [1] was performed to validate McSEE. We calculated dose values for two source types provided in ICRP-145: broad beam and industrial radiography point source. In the case of broad beam, effective dose was calculated by irradiating the adult male and female MRCPs in the antero-posterior (AP) direction for photons and electrons (10 keV - 10 MeV) and neutrons (10^{-9} MeV – 100 MeV). In the case of industrial radiography point source, the brain, lung, and colon doses were calculated using the adult male MRCP for ^{192}Ir, ^{137}Cs/^{137m}Ba, and ^{60}Co point sources located at 0.005, 0.1, 0.3, 1, 1.5, and 3 m away from the lower torso in anterior direction. Figure 4 illustrates the effective dose and organ dose values calculated using McSEE, along with the ICRP-145 values. Results for all cases show good agreements within 10% deviation, validating McSEE.

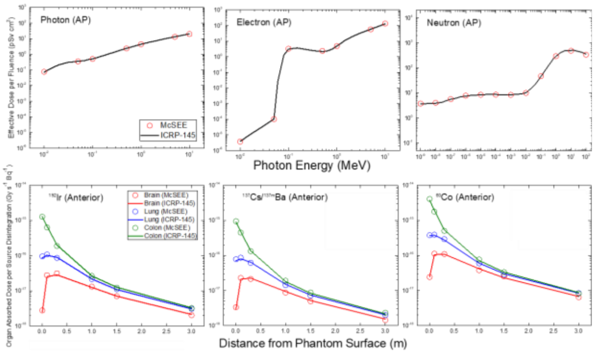

Figure 4. Comparison of effective and organ dose values calculated using McSEE and corresponding ICRP-145 values

5. Conclusion

In this study, McSEE (beta 1), a mesh phantom-based visual-aided Monte Carlo dose calculation code, was developed and introduced. McSEE is expected to facilitate the Monte Carlo dose calculation for radiation workers and regulators while providing accurate dose results. Before the official release, McSEE will be thoroughly verified and validated in cooperation with the worldwide expert institutes (e.g., ICRP, KINS, etc.). Then, McSEE will be distributed to the public as a reference dose calculation code through an upcoming ICRP Publication being prepared by TG112.

REFERENCES

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