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Setup of HDRK-Man voxel model in Geant4 Monte Carlo code

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1. Introduction

Many different voxel models, developed using tomographic images of human body, are used in various fields including both ionizing and non-ionizing radiation fields. Recently a high-quality voxel model/ named HDRK-Man, was constructed at Hanyang University and used to calculate the dose conversion coefficients (DCC) values for external photon and neutron beams using the MCNPX Monte Carlo code [1-2].

The objective of the present study is to set up the HDRK-Man model in Geant4 in order to use it in more advanced calculations such as 4-D Monte Carlo simulations [3] and space dosimetry studies involving very high energy particles. To that end, the HDRK-Man was ported to Geant4 and used to calculate the DCC values for external photon beams. The calculated values were then compared with the results of the MCNPX code. In addition, a computational Linux cluster was built to improve the computing speed in Geant4.

2. Methods and Results

2.1 HDRK-Man Voxel Model

The HDRK-Man voxel model was constructed by using high-resolution color photographic images obtained by serial sectioning the cadaver of a Korean adult male [4]. The voxel model, which has been adjusted to the Reference Korean data, is 171 cm in height and 68 kg in weight and composed of ~30 million voxels whose size is 1.981 × 1.981 × 2.0854 mm^3.

2.2 Setup of HDRK-Man in Geant4 Code

Geant4 is an object oriented toolkit based on C++ for Monte Carlo particle transport and has been used in many different applications including high-energy physics, medical imaging, radiation therapy, space dosimetry, and radiation protection [5]. This code is an open source distribution and provides many useful examples.

In the present study, the HDRK-Man was ported to Geant4 using the *G4VNestedParameterisation* class which can handle a large number of voxels. The source code was based on the extended example 'RE02' provided in the Geant4 distribution package. Figure 1 is the HDRK-Man drawn by Open-inventor visualization tool in Geant4.

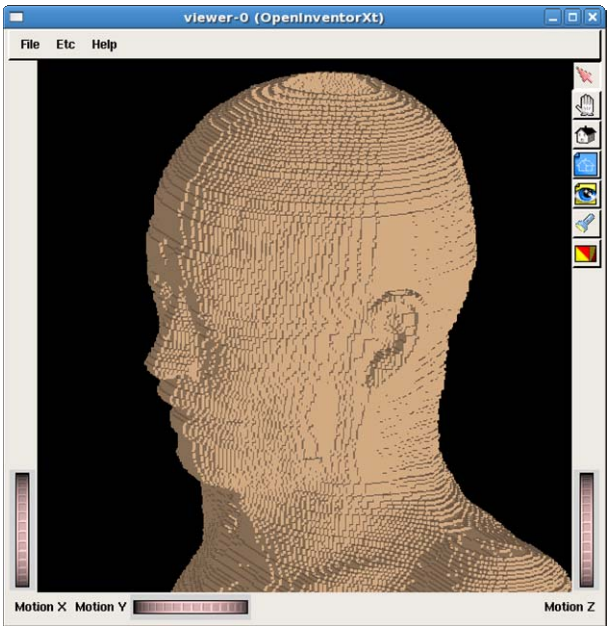

Fig. 1. HDRK-Man voxel model in Geant4.

2.3 Dose Conversion Coefficients

The Geant4 Monte Carlo simulations were performed to calculate the organ doses of the HDRK-Man for 12 external photon energies within the range of 0.015 - 10 MeV for the anterior-posterior (AP) irradiation geometry. The deposited energies in the organs were calculated by using the *G4PSEnergyDeposit* scorer class. The standard electro-magnetic package of Geant4.9.1.p02 was used for physics processes. The statistical errors in the deposited energies were less than 3% except for 0.015 MeV, for which the errors were much higher. The result of the calculation was converted to DCC values of a weighted dose with the tissue weighting factors in ICRP-103 [6]. Here, it should be noted that the weighted dose is not an effective dose, but very similar to it. The only difference is that the weighted dose is calculated using only the organ doses in a male phantom.

The results (i.e., DCC values) of Geant4 agreed well with those of MCNPX. The maximum difference was less than 27%. The small discrepancies seem to stem from the differences in physics model and scoring method between these two codes.

2.4 Parallel Monte Carlo Calculation of Geant4

It was found that the computation time of Geant4 was about 5 times when compared with MCNPX for an identical simulation case. To improve the speed of calculation, a computational Linux cluster was built for Geant4 by linking 3 personal computers (or, 12 CPUs) equipped with a 2.40 GHz Intel Core™ 2 Quad Processor Q6600 and 2 GB RAM. The cluster was built by using Rocks-OS which is an open-source Linux cluster distribution. The parallel calculation of Geant4 was successfully achieved by the method suggested Sutherland et al [7]. Consequently, the computation time was reduced by an order of magnitude.

3. Conclusions

In the present study, the HDRK-Man was successfully ported to Geant4. The computing speed of Geant4 was much slower when compared with MCNPX, but the problem was addressed by building a Linux cluster for Geant4. The HDRK-Man is now ready to be used in various dosimetry calculations with Geant4.

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