Recent Updates to Radiation Organ Dose Estimation Tool PIMAL

Hatice Akkurt, Dorothea Wiarda, and Keith Eckerman

Oak Ridge National Laboratory, P.O. Box 2008, MS 6170, Oak Ridge, TN 37831, akkurth@ornl.gov

INTRODUCTION

A computational phantom with moving arms and legs and an accompanying graphical user interface, PIMAL, was previously developed to enable radiation dose estimation for different postures in a user-friendly manner [1]. This initial version of the software was useful in adjusting the posture, generating the corresponding MCNP input file, and performing the radiation transport simulations for dose calculations using MCNP5 [2] or MCNPX [3]. However, it only included one mathematical phantom model (hermaphrodite) and allowed only isotropic point sources. Although it was useful for training purposes as well as reducing analysts' time, the capabilities were somewhat limited. Recently, the software was enhanced by adding two more mathematical phantom models, a male and female, and the source features were enhanced significantly by adding internal and external source options in a pull-down menu [4].

Currently, the software is being modified further to include the International Commission on Radiation Protection's (ICRP) reference male and female voxel phantoms [5]. Additionally, one of the case studies, analyzed and presented earlier [6], is being extended and incorporated into the software. This paper describes recent updates to the software.

DESCRIPTION OF WORK

Although the initial version of the software included only a mathematical hermaphrodite phantom, the features and models in the software are constantly being enhanced by adding more phantoms as well as other options to enable dose assessment for different configurations/cases in a user-friendly manner.

In this latest version of the software, ICRP's recently released reference male and female voxel phantoms are included in a pull-down menu. The male and female models are described using 7 and 14 million voxels, respectively.

One of the challenges for voxel phantoms has been with the display, especially for three-dimensional (3D) visualization. Using the software, the male and female voxel phantoms can be displayed in both 2D and 3D. For 3D display, the transparencies of the organs can be changed using the menu. ICRP's male phantom model in 3D and 2D as part of this software is shown in Fig. 1. The skin and soft tissue of the 3D figure, shown on the left, are shown as transparent. For 2d display, shown on the right, the view and display planes can be changed using the interface.

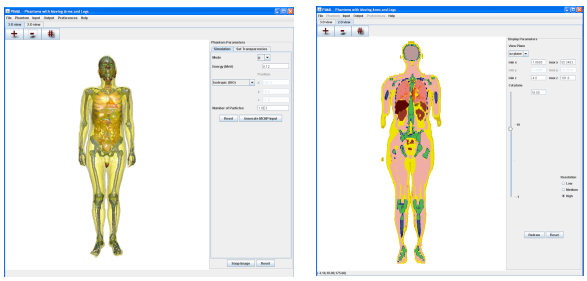

Fig. 1. ICRP's male phantom model displayed in interface in 3d (left) and 2d (right).

A set of predefined internal and external sources is included in a pull down menu. Internal sources are assumed to be uniformly distributed within the selected organ. For external sources, in addition to a point source, the user can select ICRP's standard external exposure geometries (AP, PA, LLAT, RLAT, ISO) from the pull-down menu. Furthermore, in this version, the source points can be displayed using the interface. A series of benchmark computations, using the input generated with the software, for monoenergetic photon sources for the standard ICRP external exposure geometries have been performed using MCNPX. For photons, the source energy range varied from 80 keV to 10 MeV. The computations were performed on a Linux cluster using 20 million particles at each energy. To reduce the statistical uncertainty below 1-2% at lower energies, the number of particles was increased to 100 million. The computational results showed that the computed organ dose values are in excellent agreement, within statistical fluctuations, with the values reported in Ref. 5.

In addition to voxel phantom models, a case study, which was analyzed and presented earlier [6], is being extended and incorporated into the software. This case study included simultaneous estimation of patient and physician doses during an interventional cardiology procedure for male patient and physician. Now, the user is given the option to choose different combinations of patient and physician gender. Further, the user can also change the distance between the table and floor surface, patient-to-physician distance, and lead shield thickness and generate the corresponding MCNPX input file for the analysis. The front and side views of the geometry for female physician and male patient are shown in Fig. 2. In

this configuration, the patient is lying on a table, which is 60 cm away from the floor surface, the source is placed under the table, and the physician is standing behind a lead shield to perform the procedure. Table and lead shield are shown as transparent.

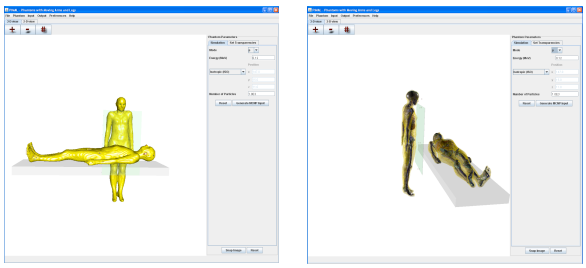

Fig. 2. Representation of patient-physician model for a female physician and male patient. The front view is shown on the left and side view is shown on the right.

The equivalent organ dose values for the female physician as a function of tube voltage (left) and the source energy spectrum for these voltages (right) are shown in Fig. 3. The computations were performed using MCNPX on a Linux cluster using 10^9 particles; the relative error in computed dose values was less than 1%.

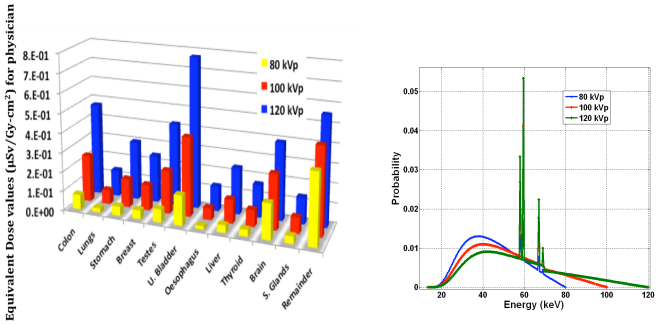

Fig. 3. The equivalent dose values, in µSv/Gy-cm^2, for female physician as a function of tube voltage (left) and the source energy spectrum for each tube voltage (right).

The case presented in Ref. 6, included the analysis for posture effect for the physician using hybrid phantom model, in which the anatomy is described using combination of mathematical and voxel geometry. Although, at the moment, it is not possible to change the physician's posture and generate the corresponding MCNPX input file automatically using the software, posture change would be possible once the hybrid phantom models are incorporated into the software.

SUMMARY AND FUTURE WORK

The software is being updated to perform dose calculations for mathematical as well as voxel phantoms for different scenarios. In this version, in addition to the ICRP's reference male and female voxel phantoms, a case study is included in a pull-down menu in the interface.

Because the software is coded in Java using Java3d features, it is operating system independent. To date, the software has been tested on Windows (including XP, 7, and Vista), Mac, and Linux operating systems. It should be noted that the software does not include MCNP/MCNPX, which should be obtained from RSICC.

In future work, additional phantoms, including hybrid phantom models will be incorporated into the software to enable organ dose estimations for realistic exposure geometries and postures. A library of input files for selected case studies will be included in the interface. Once complete, the software will be useful for training purposes as well as assisting the user for analyzing different scenarios.

ACKNOWLEDGEMENT

The authors would like to thank the U.S. Nuclear Regulatory Commission (NRC) for supporting this work.

This manuscript has been authored by UT-Battelle LLC under Contract No. DE-AC05-00OR22725 with the U.S. Department of Energy. The United States Government retains and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

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