A Dosimetric Reconstruction Simulation Code Based On Geant4 and Voxel Phantom for Radiological External Photon Exposure Accidents

Yuan ZHAO, Liye LIU *, Hongjuan PAN, Baowei CHEN, and Qinjian CAO

Department of Health Physics, China Institute for Radiation Protection

Taiyuan, Shanxi Pro. ,030006, P.R.China

中国辐射防护研究院 China Institute For Radiation Protection

Left: Yuan ZHAO, right: Liye LIU*, liuliye@cirp.org.cn

INTRODUCTION

Dosimetric reconstruction is one important issue to evaluate biological consequence after radiological accident. The physical dosimetry approach for dose reconstruction is based on either real physical phantom experiments or numerical simulation techniques. Monte Carlo simulation together with human voxel phantom, being the-state-of-art technique, provides a more powerful capability to assess the organ dose to victim since its faithful and flexibility simulation. This paper presents a new Monte Carlo simulation code, called VDOSE, dedicated to dosimetric reconstruction purpose for external photon radiological accident based on Geant4 and human voxel phantom. VDOSE can calculate not only the organ dose but also the dose distribution of the victim, so it could be a kind of technical support for surgery treatment.

METHODS

VDOSE is a user-friendly graphical user interface (GUI) program developed completely in the C++ language. It can entirely reconstruct the external photon source accident by constructing the source terms, victims, environments and shields in structures and positions, and show it on the screen in three dimensions. Then VDOSE will calculate the organ dose and / or dose distribution of the victim and save the results.

Human phantom

Depending on the victim, two kinds of human voxel phantom are used: if possible, construct the personalized voxel phantom of the victim from CT or MRI images, otherwise, use the constructed reference phantom. Here, the Chinese Reference Adult Male (CRAM) voxel phantom is recommended.

Source term

There need several parameters to define the source term, for example, source type, source shape, constituent radionuclides, nuclides activities, exposure time. In the current vision of VDOSE, the source type is just gamma ray. The source shape could be a point, a plane, a volume or any shape that could be generated with a formula by sampling. This is based on the C++ class of G4VuserPrimaryGeneratorAction and accompanied with a user interface module.

Environments and shields

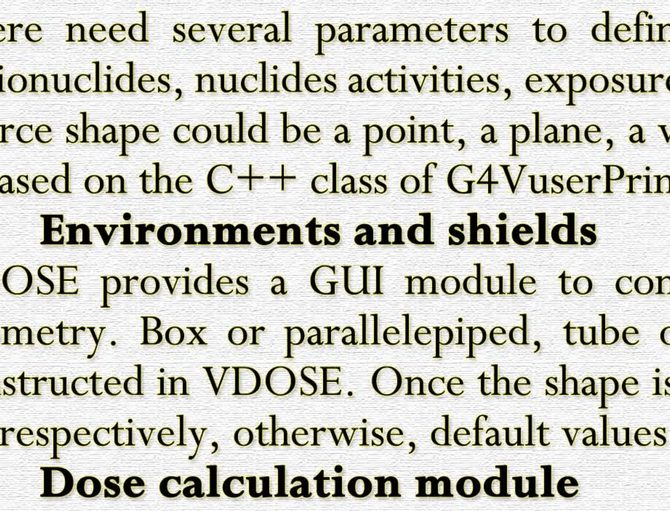
VDOSE provides a GUI module to construct simple environments and shields. This module is based on Geant4 geometry. Box or parallelepiped, tube or cylindrical section, and other geometry that Geant4 supports can all be constructed in VDOSE. Once the shape is defined, transformations like translation and rotation, and materials must be set respectively, otherwise, default values (no translation, no rotation and material is vacuum) will be used.

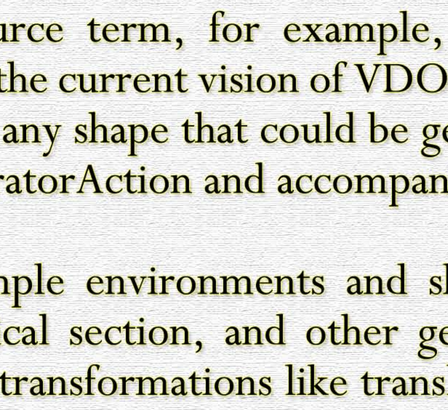
Dose calculation module

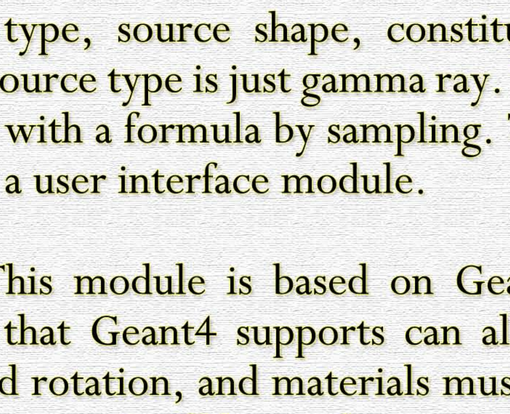
The Livermore based models are set as the physical interaction models in this module, which are G4LivermoreXXModel by name in the Geant4 classes. All interactions of photon and electron are considered, and the cut ranges of them can be set by the user (default value is 0.1mm). When the simulation starts, the dose calculation module will record the absorbed dose of each voxel of the phantom. Thus, the dose distribution and organ dose (summing up all voxels of this organ) will be calculated statistically.

3D Display module

This module is developed based on the Visualization Toolkit (VTK).







Left: View of VDOSE; Middle: CRAM Voxel Phantom;
Right: Dose distribution of a calculation result

VALIDATION

To validate this code, some calculations with a voxelized Alderson RANDO phantom were made to compare the real experiments which were carried out using the same physical Alderson RANDO phantom with thermo-luminescence dosimeters (TLDs) for gamma source irradiation. The preliminary results show good agreement between the calculations and measurements, most of the relative deviations are within ±15%.

Left: Physical RANDO model;
Middle: CT model;
Right: Voxel model