Epp – A C++ EGSnrc User Code for Monte Carlo Simulation of Radiation Transport

Jonas Lippuner, Congwu Cui, Idris. A. Elbakri, Harry R. Ingleby and David N. M. Di Valentino
Division of Medical Physics, CancerCare Manitoba, Winnipeg, Manitoba, Canada

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Purpose

Epp (Easy particle propagation) is a user code for the Monte Carlo simulation package EGSnrc that can be used for x-ray imaging and dose calculation.

Introduction

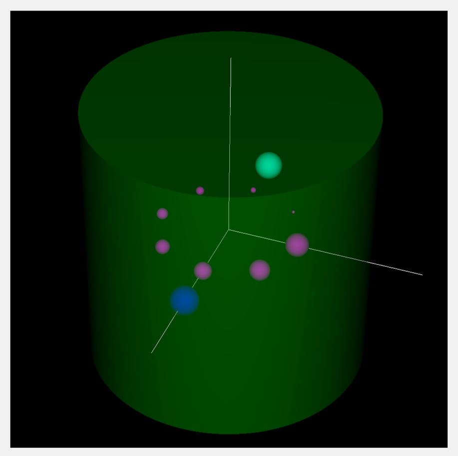
Monte Carlo simulations are very useful for x-ray imaging and dose calculation in radiation therapy. Epp was specifically designed for x-ray scatter analysis, but can also be used for dose calculation and could easily be modified or extended for other applications as well.

Epp is a user code for the widely used EGSnrc code system, similar to DOSXYZnrc but without many of its restrictions. The EGSnrc code system provides a solid physics model and the EGSnrc C++ class library is used to model the simulation geometry and particle source.

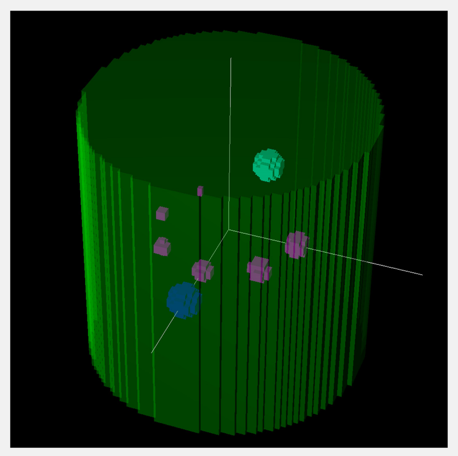
Epp is freely available under the GPL licence. Contact jonas.lippuner@cancercare.mb.ca to obtain a copy.

Simulation Geometry

While the simulation geometry of DOSXYZnrc is restricted to a voxelized volume, Epp uses a library of analytically defined geometries such as boxes, spheres, cylinders, cones etc. to construct simple as well as very complex simulation geometries. Voxelized volumes can also be simulated. In fact, Epp supports the DOSXYZnrc phantom file format and can integrate a voxelized phantom from an *.egsphant file directly into the analytical geometry.



Analytically defined phantom



Same phantom voxelized to 64 x 64 x 64 voxels

The figures show the difference between an analytical and a voxelized phantom.

The voxelized phantom is only an approximation to the analytical geometry.

Particle Source

In contrast to the limited number of pre-defined sources available in DOSXYZnrc, Epp provides sources constructed from abstract shapes such as points, lines, rectangles, circles, rings etc. They can be used to construct parallel, collimated or other types of sources. There is also a Gaussian shape to model non-uniformly irradiating sources. Multiple sources can be combined to form a collection of sources where each individual source can be assigned a statistical weight.

Comparison

Feature	Epp	DOSXYZnrc
language	C++	Fortran
simulation geometry	analytically constructed	restricted to voxelized volume
particle source	constructed from abstract shapes	pre-defined sources
input file format	flexible, hierarchical structure	fixed sequence of parameters
dose calculation	no normalization	normalized to incident fluence
x-ray imaging	built-in	n/a

Performance	Epp	DOSXYZnrc
x-ray imaging		
analytical	1	n/a
voxelized	2.54	3.94
dose calculation		
voxelized	1	0.74

Performance values are CPU time scaled for comparison. Imaging: Epp 5.5 min / 13.9 min (analytical / voxelized), DOSXYZnrc 21.6 min. Dose: Epp 23.6 min, DOSXYZnrc 17.4 min. The simulations were run with 8 processes on 8 3.16 GHz processors and 16 GB RAM.
All simulations ran 10^9 histories and used the phantoms shown in the Simulation Geometry section, which consist of a 12 x 12 x 12 cm 50/50 breast tissue cylinder inside a 12.8 x 12.8 x 12.8 cm air cube. The cylinder contains one glandular and one adipose sphere and several polyethylene spheres. Source and detector were placed 25 cm away from the centre of the phantom. The source was a monochromatic (38 keV) point source collimated to the front face of the phantom. The detector was made up of 512 x 512 square pixels with side length 1 mm.

Flexibility

Epp and the geometry library are written in C++ and are designed to be easily modifiable and extendible. If, for example, the user requires a particle source that cannot be constructed with the provided shapes, she can implement a new shape based on an existing one. The user only needs to implement the new aspects of the shape and can rely on the base functionality of the existing shape. The same applies to simulation geometries.

The Epp input file consists of key-value pairs in a key-subkey structure, which makes it very flexible and human-readable. Epp also provides the ability to reference other files so that a simulation can be broken up into several input files, which can be re-used and shared among users.

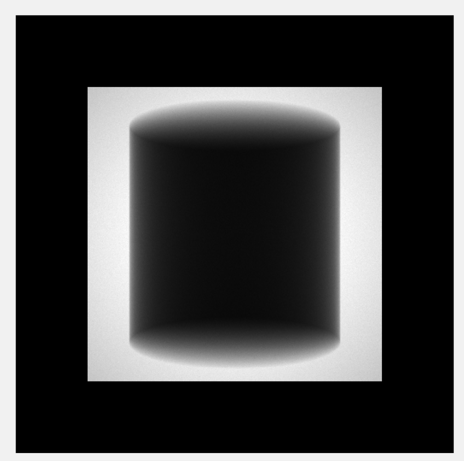
Dose Calculation

Epp can calculate the dose deposited in each voxel of a voxelized volume, similar to DOSXYZnrc. But in addition to the voxelized volume, the whole simulation can contain additional analytical geometries.

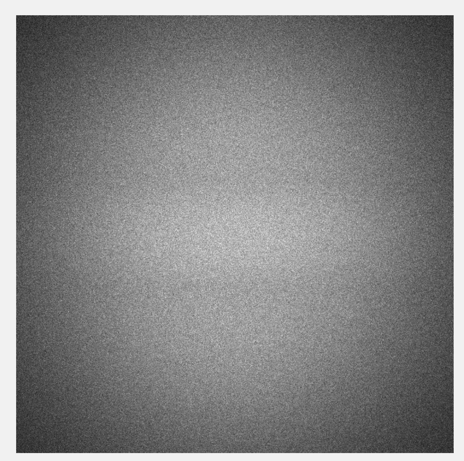
X-Ray Imaging

Epp has built-in support for x-ray imaging. The user can define a virtual detector and Epp will generate an image of the total number of particles and/or total energy deposited in each pixel of the detector.

For the purpose of x-ray scatter analysis, Epp can also generate separate images of the primary beam, single Compton, single Rayleigh and multiple scattered photons.



Primary beam



Single Compton Scatter

The figures show the photon count images of the primary beam and single Compton scatter of the simulation described at the bottom of the Comparison section.