PA1-41

The Numerical Simulation of Cultural Heritage Treatment by Monte Carlo Method

Volodymyr Morgunov
Ukrainian Engineering and Pedagogical Academy, Kharkiv, Ukraine

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Abstract

Radiation processing techniques are in wide use in for disinfection and consolidation of archived materials and cultural heritage artefacts. The maximum dose (Dmax), which can be absorbed by product without changing its properties, is known from research phase. So, minimal absorbed dose (Dmin) should be transferred to product to achieve disinfection and this dose shouldn't be more than maximum dose. The location and magnitude of the dose minimum and maximum is critical to process control, optimized irradiation configurations and it affects both disinfection and product properties.

Reliable product dose-maps are necessary for identification of these critical process parameters and may involve time consuming and laborious dosimetry. In some cases determination of the dose-maps is difficult to produce by experiment. Such cases are very often occur during cultural heritage artefacts radiation treatment. In such situations the numerical simulation can be used.

Process technological and calculated parameters

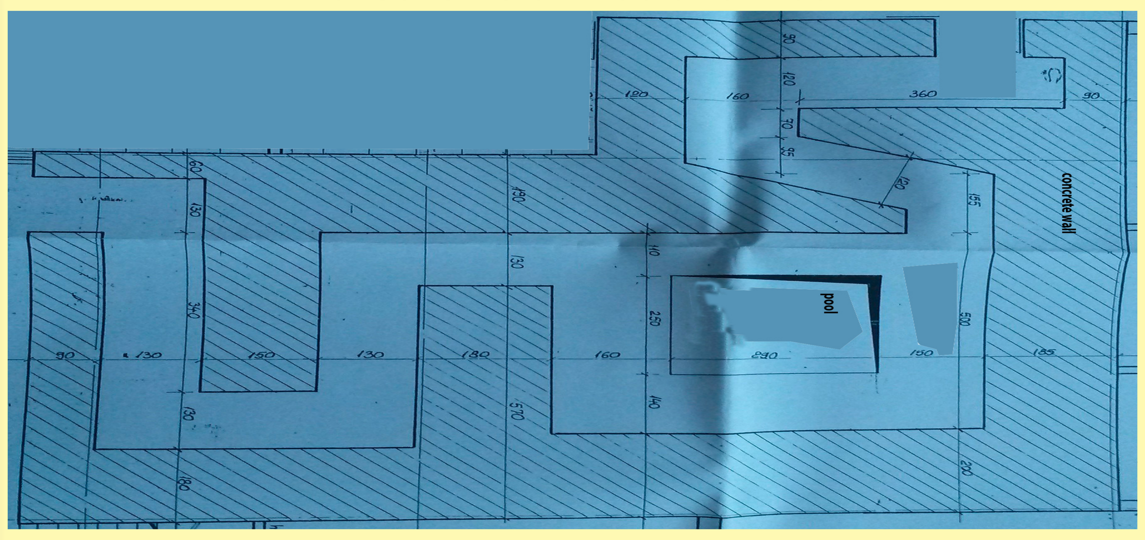
Process technological parameters which should be input into code:
1. Irradiation chamber. Geometry of irradiation chamber and its composition.
2. Treated objects. Geometry of treated object and its composition. Position of treated object relative to irradiation source and irradiation chamber. Special attention should be paid if treated object are moving.
3. Irradiation source. The type, activity, position, energy, geometry, spatial distribution of irradiation source.
4. Detectors. Location, dimension, composition and type of detectors.
5. The physical processes.

Calculated parameters are following:
1. Dmin;
2. Dmax;
3. Time of treatment;
4. Dose map.
5. Absorbed dose rates

Results of import CAD-files into code

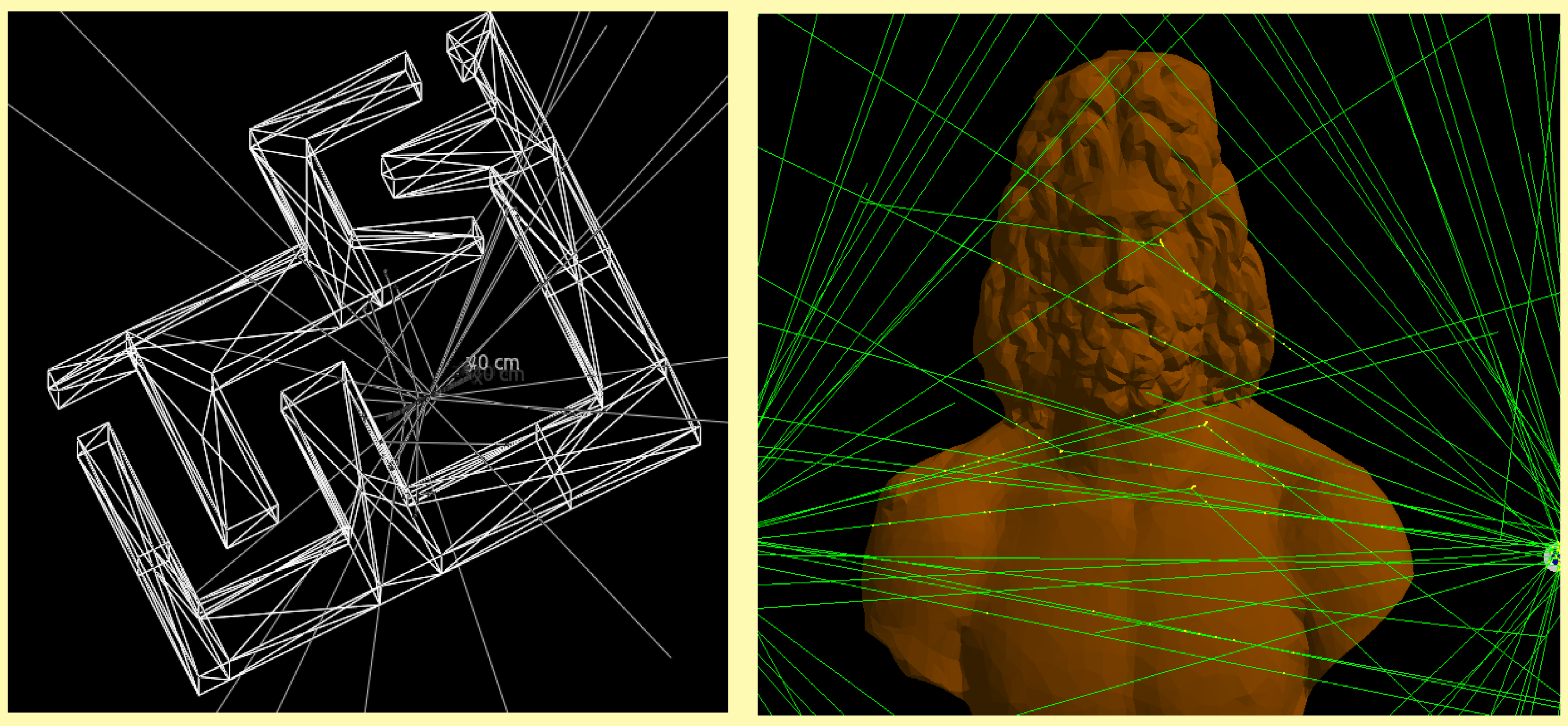
To input complicated geometry into simulation CADMesh library was used [1].

Initial scheme of irradiation room



Treated object

View of irradiation room and treated object in simulation



Choosing of a toolkit for the simulation of the passage of particles through matter

GEANT4 [3] was chosen as a toolkit for the simulation of the radiation treatment because of
1. GEANT4 has the multithreading mode (LINUX version).
2. GEANT4 uses modern programming language C++.
3. This toolkit is free
4. A long-time development
5. Good technical support
6. GEANT4 has possibility to input complex geometry of irradiated objects

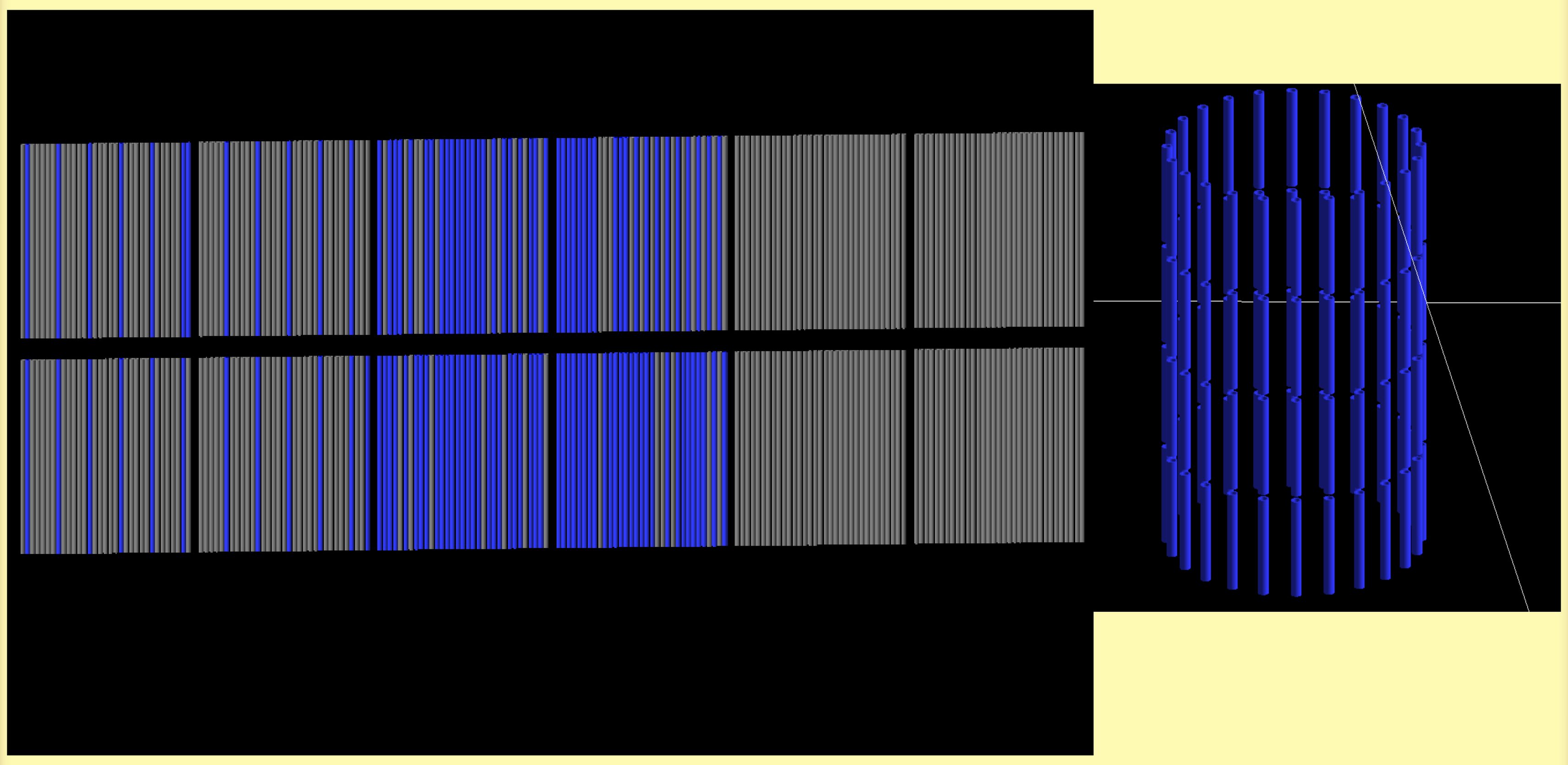
References

[1] Poole, C. M., Cornelius, I., Trapp, J. V., & Langton, C. M. (2012). A CAD interface for GEANT4. Australasian physical & engineering sciences in medicine, 35(3), 329-334.
[2] Si, Hang. "TetGen, a Delaunay-based quality tetrahedral mesh generator." ACM Transactions on Mathematical Software (TOMS) 41.2 (2015): 11.
[3] Agostinelli, Sea, et al. "GEANT4—a simulation toolkit." Nuclear instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment 506.3 (2003): 250-303.

Gamma radiation source in code

C++ class was developed to input data on panoramic irradiator into the code. Data on panoramic irradiator can be read from .csv (comma-separated values) file. The following data are in this file:
1. Type of panoramic irradiator: plaque or cylindrical.
2. Type of used in the source rack pencils.
3. Amount of modules.
4. Amount of frames.
5. Amount of pencils per module.
6. Amount modules per frames.
7. Amount frames per source rack.
8. Activity of each pencil on certain date.

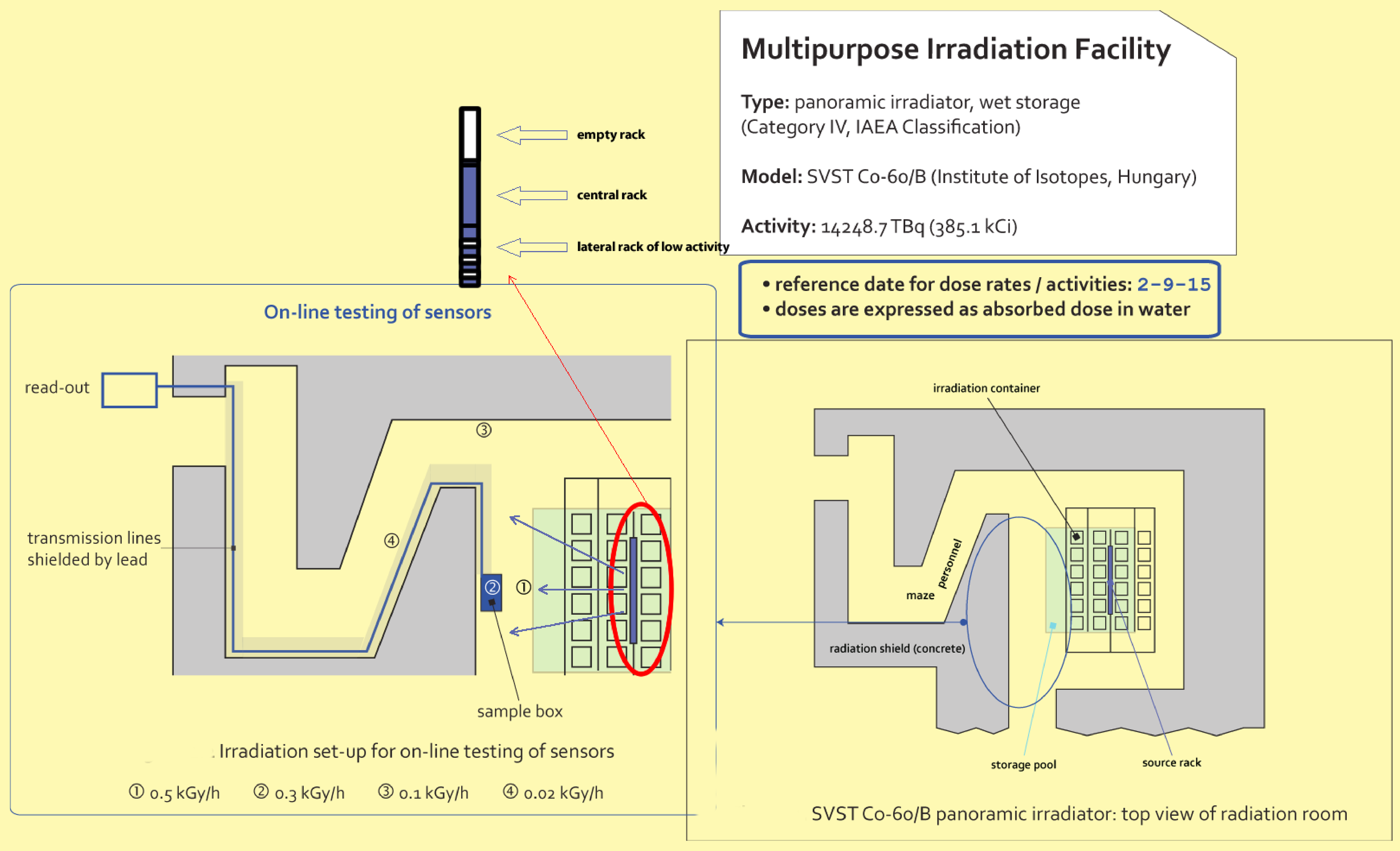
The developed C++ class read these data from .csv file and forms source rack in the code.
The possibility of empty places instead of pencil and "dummy" pencils is provided.



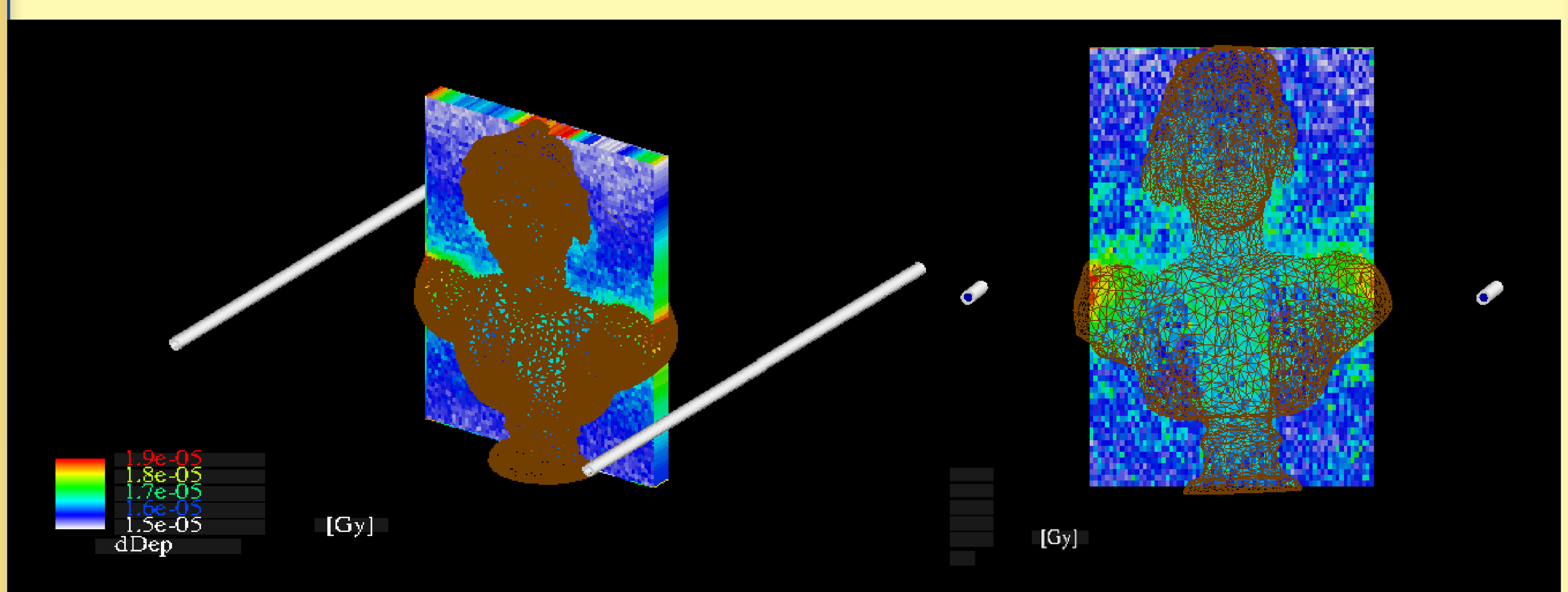
Radiation source in simulation code. Its construction and dimension were taken from Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH, Bucharest, Magurele, Romania). Radiation source consist of 3 frames each of which contain 4 modules. Each module consist of 33 stainsteel pencils with Cobalt-60. Blue pencils - active ones, grey are inactive pencils.

Verification of developed code

It was compared experimental measurements with simulated dose rates. The average ratio measurement and simulated is 0.95.



Preliminary result of simulation



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