NOVEL TECHNIQUE FOR RADIATION DOSE VISUALIZATION IN LARGE SPACE

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Introduction.

From the point of view of a medical physicist the creation of 3D visualizations to illustrate radiation dose distribution within a room or building is a very useful tool for radiation protection planning.

This study describes a novel technique for 3D visualization of radiation field.

The developed method is shown to be effective and compatible with many CAD software packages.

Radiation protection planning could be greatly enhanced by providing staff with a simple and easy to use tool to make simulations and generate 3D visualizations.

Purpose.

The aim of this study is to create and develop a novel method and software for 3D visualization of radiation fields in large space. This study sought to create the 3D visualization method that any potential user could emulate and adapt for any of a variety of purposes.

This tool furthermore could be a useful for generation of 3D visualizations for augmented reality applications.

Visualization generation process.

The generation process of 3D radiation field can be divided into 4 phases as shown in Figure 1.

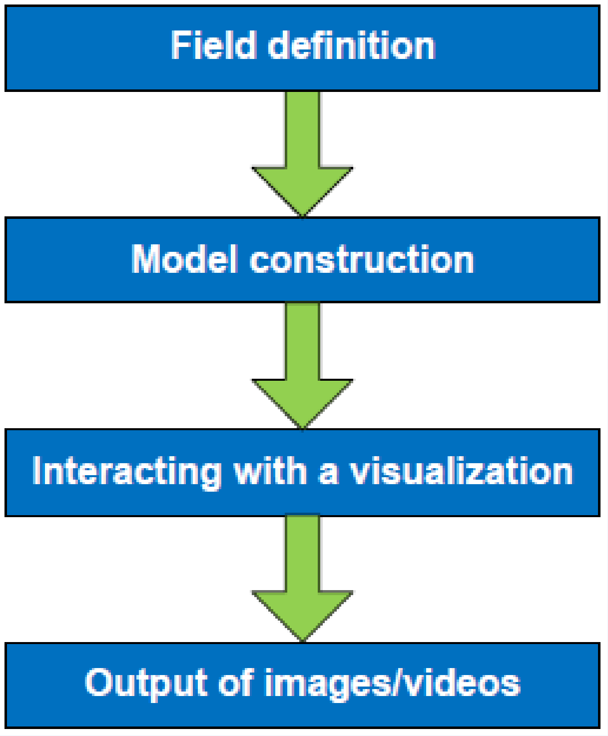


Figure 1 - Four phases to visualizing a radiation field

Field definition.

The first step is defining of a radiation field.
A radiation field is a term in medical physics which most commonly refers to the particle fluence, and also often the energy distribution of ionizing radiation within a medium, volume or space.
The key feature of a field is a quantifiable trait, such as the rate of particles entering each volume unit of space that varies throughout all environment.

Model construction.

The radiation field model construction process is based on iterative, point by point technique. Building a model from many small parts potentially gives more options for errors during construction, but alternatively the construction method is conceptually very easy to understand and adapt for specific projects and programs. Besides, utilization of fundamentally simple concepts maximizes the compatibility of this method with other 3D modeling software. The only requirements for target 3D modeling software package is that the software:

1. **allows the automation of construction actions,**
2. **allows transparency effects to be applied.**

Interacting with a visualization.

The final stage of the construction process takes place when the modeled field is used for its visualization. In this stage, viewpoints are setup for their eventual output as static images. The viewing process is entirely reliant on the construction process, as it limits which types of programs may open and view a constructed model. The assumption that the primary users will not be expert 3D modelers requires that this interaction process be as user friendly as possible.

Output of images.

Through the interaction process, it is necessary to respect a user requirement to collect and output images of the modeled field for inclusion into presentation material, reports or other media forms. The final consideration in the development of this method was that the end technique must make the process of generating this material very easy.

Visibility.

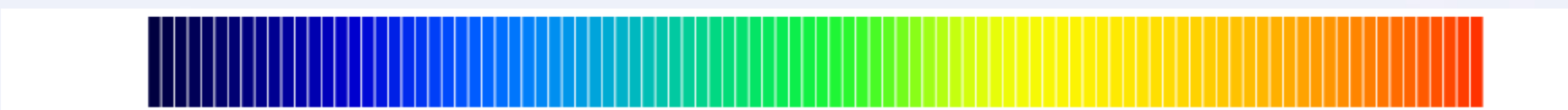
Visibility is a very important issue which needs to be considered very carefully. For a radiation field to be completely visible a computer model must allow a viewer to observe both internal and external details, like looking through a foggy window. This is an absolute requirement to allow all of the internal details within a field to be seen from external viewpoints, otherwise they would be obstructed by the outer layer of information. These details could be something such as a change of dose rate within a localized area, or depending on the type of field being modeled, it could be a change in local particle fluence quantities or other relevant factor. The visibility of non-radiation models (such as background) was also considered an equally important requirement.

Model navigation.

Navigation refers to how the end user will move around a modeled field. These movements are important feature so that the user is able to analyze a model from as many viewpoints as possible. The controls to move a viewpoint in an environment need to be very intuitive in usage. How a user establishes multiple perspectives for a scene and manipulates a model plays a key role in the overall user friendliness of this software.

Colors.

Determining appropriate colors to be used in model is the next step needs to be addressed. If models are made with non-intuitive colors, obtaining information from model become much more difficult. If a model uses too many colors it could also be difficult to review and understand the results. A set of recommendations concerning the use of color within a visualization will be required at some level to assist users in the creation of models.



Model portability to other 3D software.

Portability of a constructed model to alternative software is considered a desirable trait in this research. Once a field model has been created, its usefulness is directly related to the number of different analytical and visual applications available for user to view and analyze a model. This is primarily concerned with the data format of the 3D model. If a 3D model is stored in an openly documented and available 3D format such as the COLLADA[1.] **format (file extension *.dae) , it will be possible to use many different 3D viewers.**

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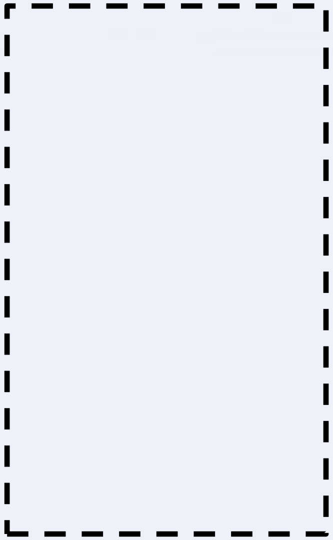
In addition to being compatible with a wide array of modeling software due to no licensing costs, the COLLADA format is based on the Extensible Markup Language (XML). This allows a COLLADA formatted file to be directly opened with a simple text editor program and properties of the file can be edited directly via the text editor. As the programming language has been selected RUBY[2.]

Model limits.

A model limit is a reference to where a radiation field model should be constructed and where it should not. There is a potential for a large amount of overhead in the development of any large or complex model. Reduction of this overhead may be possible by limiting the model to only the specific section (ROI) needed for a given scenario.



Block based methodology (1.)

A field is devided into a set of finite elements with each element containing a series of bounds, an intensity value and a central coordinate. Each element is considered to act as a single representation of an intensity value for a field within the local confines of that element. These elements are geometrically simple shapes such as cubes or boxes. These individual elements can be thought of as a physical representation of a volumetric pixel (voxel).

Block based methodology (2.)

Voxels can be used to represent data in a dimensional space as they contain both a physical location and a value at that location. Using basic shapes simplifies the arrangement of these elements into a single model where all the elements can be fitted together so their boundaries do not overlap each other. Theoretically an intensity value is not limited to a single type of information (e.g., dose rate); any type of information could be visualized using this method.

Method summary.

The method proposed for building and modeling a radiation field can be summarized as the following:

1.) A data set containing (x_n, y_n, z_n, V_n) is taken (where x_n, y_n and z_n represent coordinates, and V_n represents a value at those coordinates)

The process requires that x_n, y_n, z_n, values be at a fixed distance apart to establish a fundamental element size for that model ***(e.g., if they are all values at a 1m, 2m, 3m, etc in all directions, this process will establish that each (x_n+1) is equal to (x_n+1m) and the fundamental element size is a cube of 1m x 1m x 1m)***

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2.) A script inside the 3D modeling program is being used for reading those values one at a time and constructs an element at each location. This script includes a scale where the V value is assessed and each element is coloured based on its value.

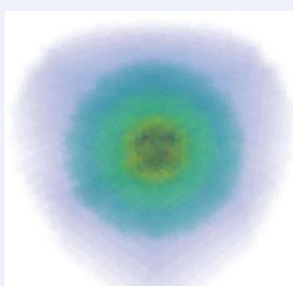
a.) The program is opened and the script is runing to calculate each (x_n, y_n, z_n, V_n) and a shape is built (centered at the coordinate or other reference point)

b.) Based on the V_n value, that new object (volume) is given a colour, material, or whatever the term the program uses to define the appearance of an element.

3.) This process then repeats until a shape has been built at all of the locations specified in the data file.

a.) During the construction process different ranges of associations can be assigned to values of V. If V is: 5> V > 3, then color = light blue which means any time a shape is built, and the V value is less than 5 but greater than 3, a color value of "light blue" will be assigned

b.) All entities within the same range will share the same color, or material property. They require transparency to be added to complete the visual effect.



<5	5 – 10	10- 15	15-20	20-25	25-30	30<
μSv/h						

Model definition.

To be compatible with the Ruby[2.] code, a text file is required which contains values in the format shown in Table 1 and Table 2.

Table 1 - Data format for ruby script

(x-coordinate)	(y-coordinate)	(z-coordinate)	(intensity-value)

Table 2 - Example data taken from text file

5	5	6	4.10
6	4	6	3.80
7	4	7	3.63
8	8	4	3.33
8	4	10	3.03
9	1	3	2.77

Each element to be constructed requires values as shown in Table 1 and Table 2. This is stored in a plain text file (.txt extension) which uses a separate line for each new element and tab delineation between values.

Example radiation field model shown in figures below.

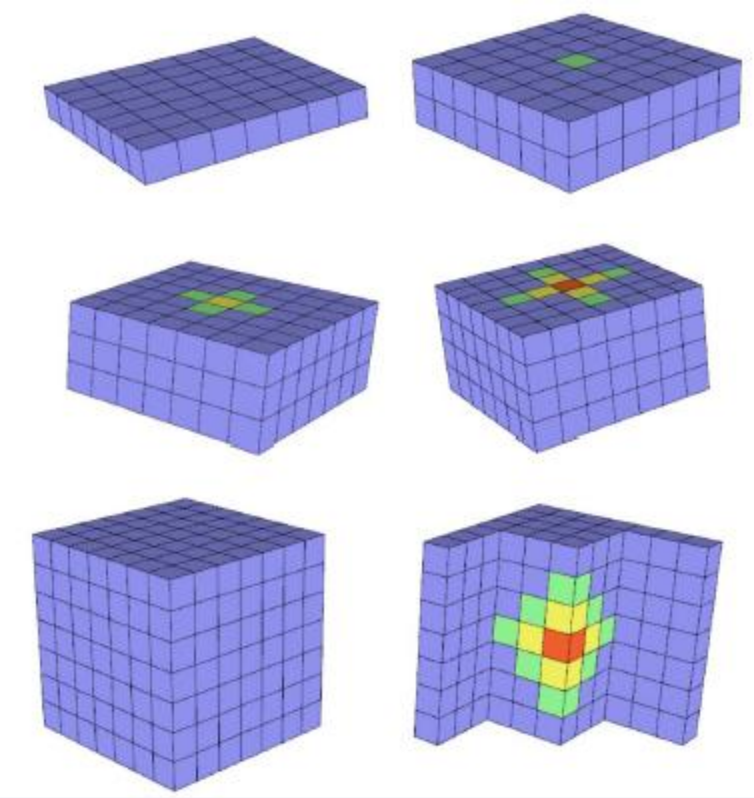


Figure 2. Example model

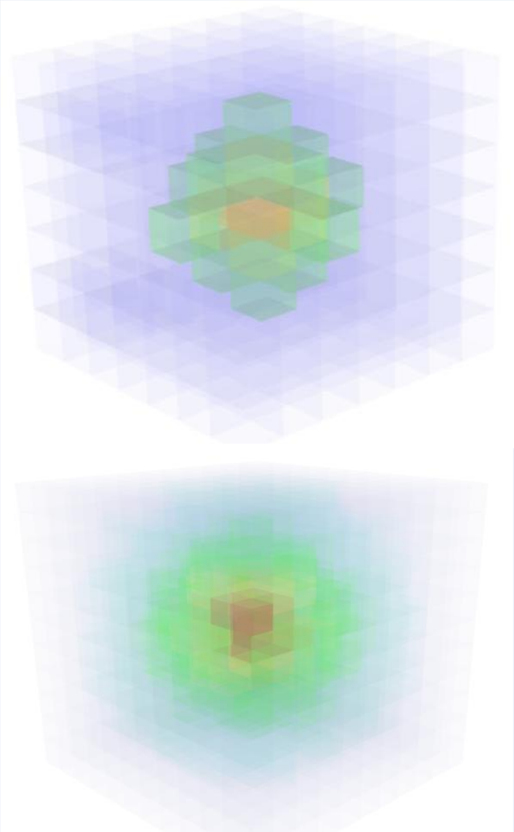


Figure 3. Example model with transparency effect applied.

Computational software approach.

A computational field model is based on Monte Carlo N-Particle (MCNP) transport code[4.]. If a nuclear physics code is able to keep a tally in multiple locations simultaneously, and provide output data in a format that is similar to (or could be made similar to via post processing) that in Table 2, then the output from that code is compatible with the model construction process. Nuclear physics code MCNP can provide a very flexible outlet for making graphical representations of more complicated scenes.

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Results.

Program accuracy was evaluated in the following stages:

1. assessment of the radiation source Monte Carlo model accuracy relative to the measurements in water phantom,

2. visualized dose model accuracy relative to the $KERMA_{AIR}$ measurements – point dose in software compared with real measurement at the same coordinate in room.

For evaluation purposes a linear accelerator Varian Clinac iX head model was created. MC simulations was accomplishedfor 6MV beam at the field sizes of 5x5 cm; 10x10 cm; 15x15 cm; 20x20 cm. Results verified relative to the measurement in IBA Blue Phantom. Comparsion of simulated and mesured %PDD shown in Fig. 4.

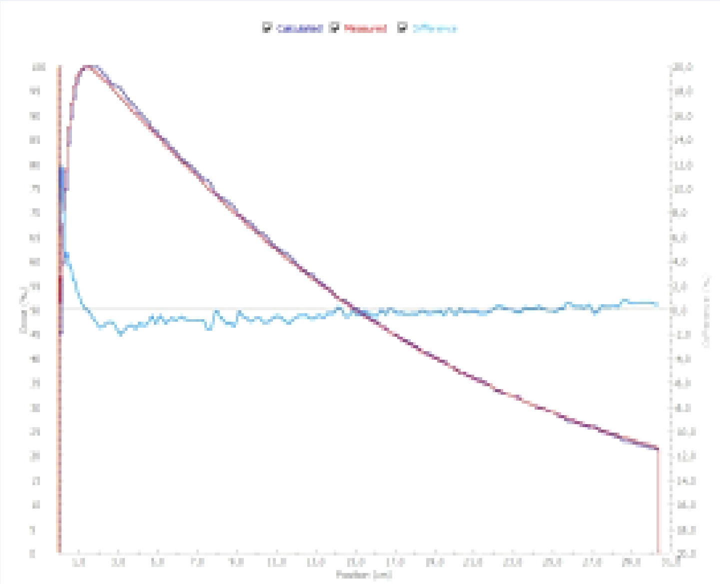

Figure 4. Comparsion of %PDD for field size 10x10cm

Similar evaluation was also conducted for dose profiles in X and Y plane. Results are presented in Fig. 5. and Fig. 6.

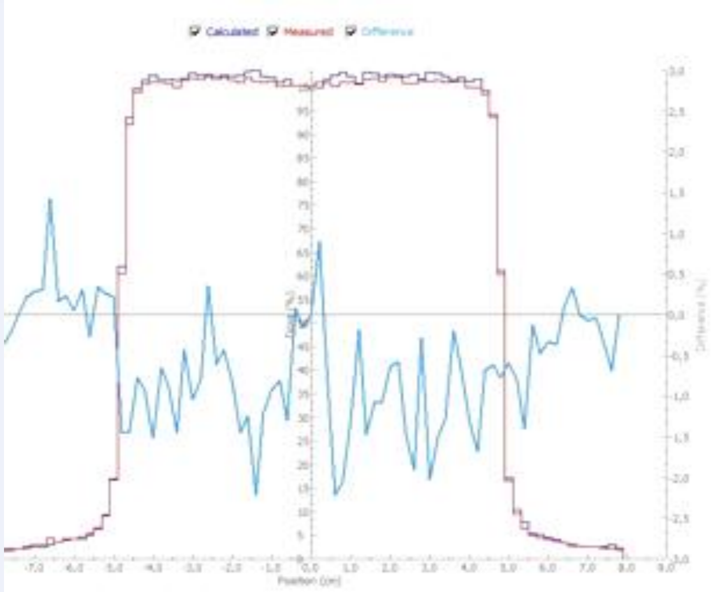

Figure 5. X plane dose profile comparsion, 10x10cm

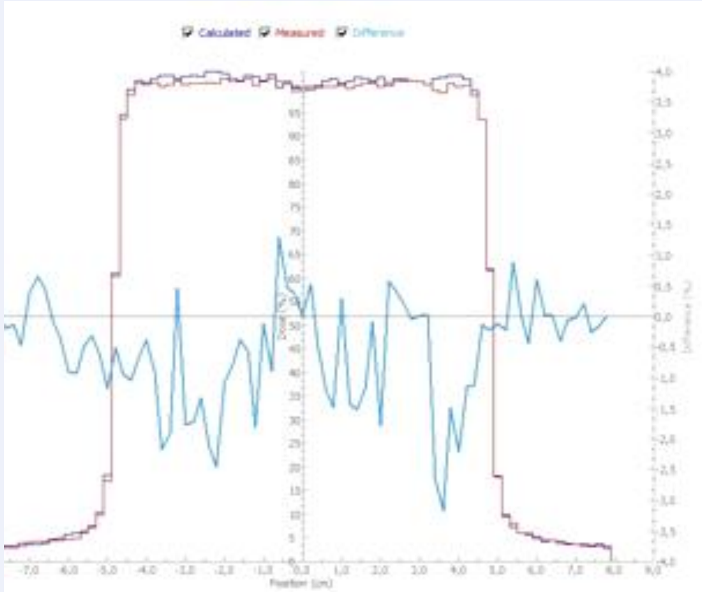

Figure 6. Y plane dose profile comparsion, 10x10cm

Established MC linac head model accuracy assessed as appropriate for the continuation of the experiment. For further evaluation of the program was created the linac bunker 3D model, with radiation source (linac) inside, as shown in Fig. 7.

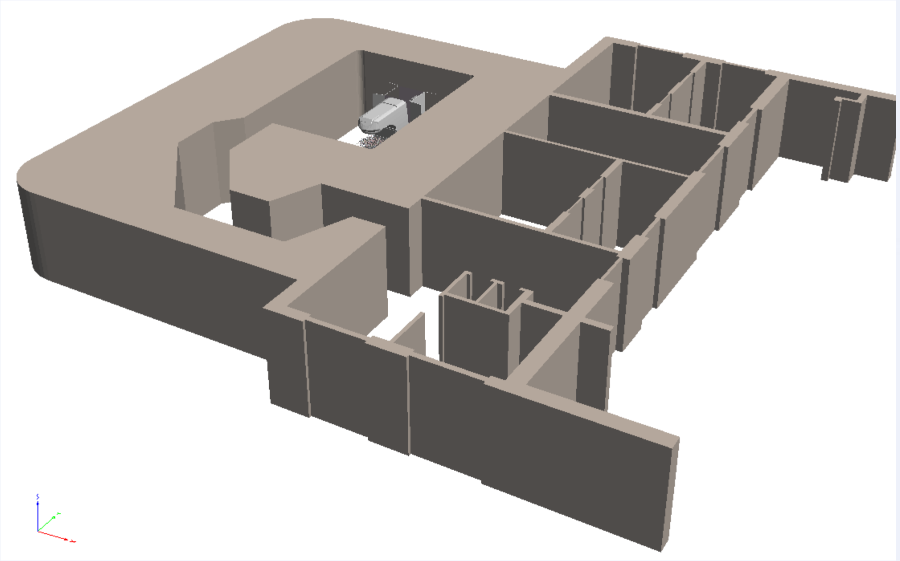

Figure 7. Varian Clinac iX bunker 3D model, data taken from Liepaja Regional Hospital, scale 1:1

Radiation source data was taken from simulations mentioned above. After completion of the visualization, point doses from model was taken for 46 points and compared with measured dose under the same conditions. Example dose visualization is shown in Fig. 8

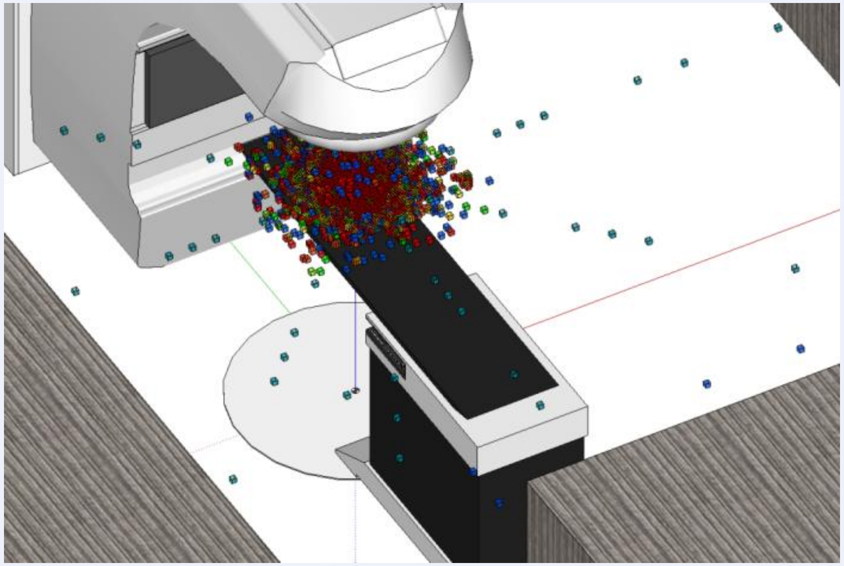

Figure 8. Experimental radiation field visualization for Varian Clinac iX, 6MV, field 40x40cm.

Results obtained vary between 3.54% and 21.09% concerning to measured dose. In addition, there is a trend that the error increases with increasing distance from isocenter. It could be explained by the fact that the precision of measurement is less at lower dose rate.

The numerical values of these trend are partly summarized in the Table 3.

Table 3.

X	Y	Z	Δ%
0	0	100	3.54
50	50	100	8.32
300	300	100	21.09

Conclusions.

In this study, a novel methodology for the display of 3D radiation fields was developed. New approach was formulated which focused on keeping the field definition process separate from the modeling process to maximize potential definition techniques.

The types of expected issues associated with 3D radiation field visualizations were discussed and analyzed. Overall design requirements for this type of program development were established and eventually shown to have been achieved. The software product obtained in this study, of course, require improvements and adjustments, but generally it has been demonstrated that it is able to operate for its intended purposes.

Further work is planned severely to work on improvement of the user interface and functionality.

Special Thanks to

Mr. Joseph Chaput, IAEA, for sharing ideas and experience from similar projects and assistance in concept design.

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Thank you for your attention!