A Generic Methodology for the Three Dimensional Visualization of Radiation Fields

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Running title: 3d Visualizations of Radiation Fields

***Abstract*–**The radiation field visualization options available for engineers, scientists and health physicists have traditionally been based in the 2d realm, with techniques such as the generation of isodose curves. From the perspective of a health physicist, the creation of 3d visuals to illustrate radiation levels within an environment is an invaluable tool both for training and radiation dose planning. This paper describes a novel technique for the creation of 3d visualizations of radiation fields. The methodology takes an input file of information stored in coordinate form with a representative value at each point and constructs elemental shapes automatically at those coordinates. All shapes are associated with an intensity value related to a pre-defined scale. The shapes are then colored and enhanced with transparency effects to complete a radiation field visualization scene.

INTRODUCTION

The clear communication of ideas within complex sciences such as the field of health physics and nuclear engineering is inherently limited by the audience's understanding of the fundamentals [1]. Communication of concepts such as varying dose rates within an environment are frequently required during the planning of activities ranging from decommissioning operations, environmental assessments to emergency response exercises and dose planning for radiation therapy. When communicating with the public the adage 'a picture is worth a thousand words' holds significant value as complex ideas are often most quickly understood with the right visual imagery [2].

Safety concepts such As Low As Reasonably Achievable (ALARA) in radiation therapy dose planning are an important aspect of any occupational health and safety program [3]. Reducing time within a field, increasing distance between a user and a source and increasing shielding are three general principals which can be used to maintain ALARA. Teaching those responsible for working in and around radiation fields about the shape, size and intensity of the radiation environment around them is an important technique to make users aware of how to take advantage of the time, distance and shielding principals effectively. Finding new and novel methods to better communicate these concepts should always be in the interest of health physicist, scientists and engineers.

There are several computer programs which have been shown capable of displaying ionizing radiation fields within three dimensional (3d) environments [4-6]. These programs are adequate for their designed purposes but beyond that they have all been created for specific purposes and for specific goals limiting their impact in broad terms. These programs are closed in design, too simplistic for general purposes and/or not widely available for the public, limiting their usefulness in industry. Intuitively it is clear that education and communication of complex ideas in the nuclear industry could be greatly enhanced by providing engineers, scientists and health physicists a simple and easy to use process to generate 3d visualizations of their work. There is a clear gap for an open and easily accessible tool to generate 3d visualizations of radiation fields which this paper seeks to address.

DEFINING A FIELD

Defining a radiation field is the first step in any visualization. A radiation field is a ubiquitous term in nuclear engineering and health physics which most commonly refers to the particle fluence and also often the energy distribution of some type of ionizing radiation within a medium, volume or other space [7]. The key feature of a field is that there is a quantifiable trait, such as the rate of particles entering each cubic centimeter of space that varies throughout an environment. The types of radiation fields of primary concern are those caused by ionizing radiation, but the work herein may be applicable to the visualization of other types of radiation fields such as those from non-ionizing sources.

METHODOLOGY

The construction methodology is conceptually straight forward to understand. A field is broken down into a set of finite elements with each element containing a series of bounds (limiting its extent in all directions), an intensity value (representing its reading) and a central coordinate location (which is in direct relation to all other elements). Each element is considered to act as a single representation of an intensity value for a field within the local confines of a space. These individual elements can be thought of as a physical representation of a volumetric pixel (voxel) [8]. 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 type of methodology.

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

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)
    a. 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 1mx1mx1m)
2. A script is prepared for the 3d modeling program being used. It reads 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 colored based on its value.
    a. The program is opened and the script is run 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 color, 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. I.e.: 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 that fall within a range will share that color, or material property. They require transparency to be added to complete the visual effect.

APPLICATION IN GOOGLE SKETCHUP

Google SketchUp 7 is a computer assisted design (CAD) software tool distributed by Google Inc. [9]. It has the benefit of not only being a very commonly used tool in industry (architectural design, construction and engineering) but it is also made freely available with some minor features removed. Two of the most prominent features are the availability of a free version of the software, and the inclusion of the Ruby language inside the program to automate construction actions. Ruby is a computer programming language designed to be open-source, conceptually easy to understand and simple to use [10]. Its inclusion within SketchUp as a scripting language allows most physical commands to be automated. Ruby's inclusion simplifies the process of automating the construction and coordination of the elemental shapes. A script was constructed in Ruby which automates the construction process described previously.

ILLISTRATIVE MODELS

Some resultant models are made available in the figures that follow.

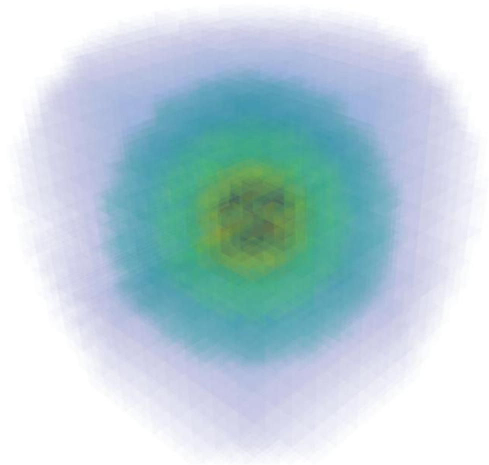

Figure 1 - 3d point source model

Figure 1 depicts the radiation fields surrounding a point source. This particular model was constructed using the methodology described combined with a simple formula representing the dose rate from a point source. The dose rate from a point source decreases by a factor of four, each time the distance from the source is doubled. This causes the spherical shape of the field to be very clear and despite the lack of a scale associated with this figure, the regions of varying intensity are very obvious for the viewer to understand.

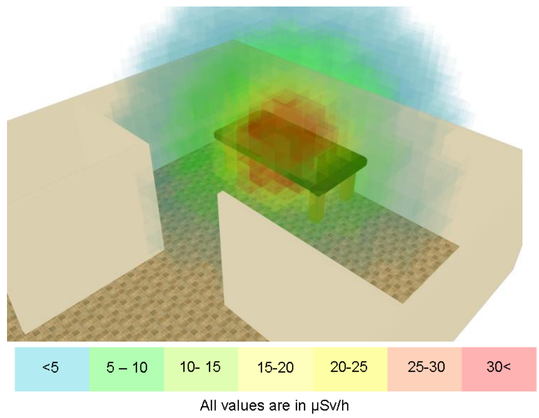

Figure 2 - Point source on a table in a room

Figure 2 takes the point source model from Figure 1 and places it into a simple artificial environment. A scale has been included to make the different radiation levels clear to the viewer and the image suddenly becomes a useful tool to illustrate to a third party how a radiation field propagates within an environment.

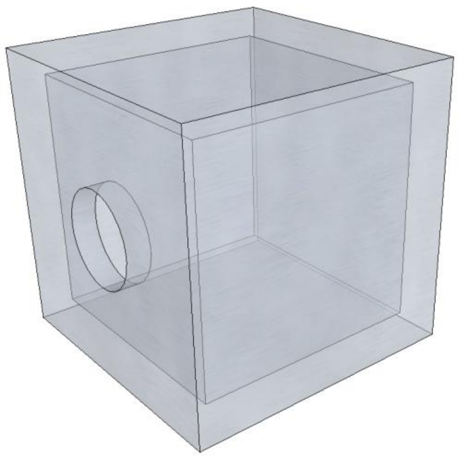

Figure 3 - Simple irradiator model (source suspended in center)

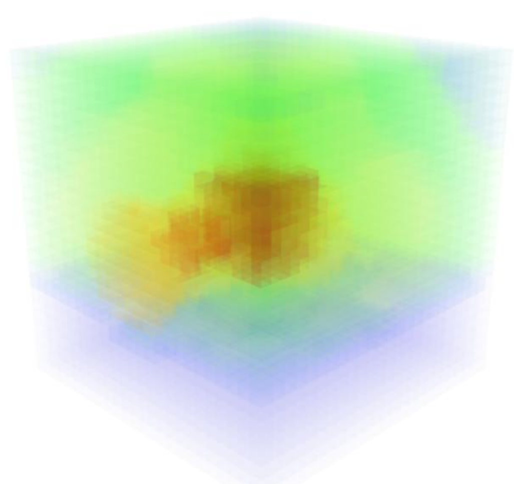

Figure 4 - Irradiator radiation field model

Figure 3 represents a very simple irradiator design. This design was built in Monte Carlo N-Particle Transport Code (MCNP) [11]. In this model the source term (Co-60) is suspended in the center of the irradiator apparatus. The radiation field model in Figure 4 was constructed by combining the visualization methodology with the mesh tally function in MCNP to establish a wide grid of detectors. This allows for a complex scene to be modeled and visualized. In this particular model the scaling is simply based on the relative particle fluence between neighboring elements. This approach illustrates how powerful imagery can be developed from very simple elements.

CONCLUSIONS

The methodology discussed and presented here can be used to create very powerful 3d images of radiation fields. Google SketchUp remains an ideal tool for its application however; any 3d modeling software which allows both for the automation of construction actions and the application of transparency effects to surfaces should be suitable to follow the same process.

Combining this methodology with freely available software such as SketchUp, the research discussed within this paper will ideally become a powerful tool for engineers, scientists and health physicists to create and display radiation fields in 3d with relative ease. These models can be used for training, ALARA planning, engineering or countless other uses. It is the hope of the author that, models such as the ones developed within this research will become as common place as a typically scatter plot or bar graph within the nuclear field.

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BIOGRAPHY

Joseph Chaput holds a Master of Applied Science (2010) and a Bachelor of Engineering (2007) both in Nuclear Engineering from the University of Ontario Institute of Technology (UOIT). His Master's thesis covered three dimensional visualizations of radiation fields. He is presently a PhD student in Nuclear Engineering at UOIT. His research includes advanced techniques for the three dimensional modeling of radiation fields, augmented reality applications in the nuclear industry and novel techniques for the reconstruction of radiation fields from sparse data sets.