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Development of voxel models from 3D surfaces: optimized methodology

Desenvolvimento de modelos voxelizados a partir de superfícies 3D: metodologia otimizada

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Abstract

Anthropomorphic models are widely used in computer simulations to calculate conversion factors for external and internal dosimetry. However, their construction is difficult and delayed due to the CT images segmentation. In last years, CAD (Computer-Aided Design) programs were used to develop new anthropomorphic models in NURBS, MESH and POLYGON surfaces. However, most of the current simulation codes don't allow entering the objects in CAD format, making it necessary to convert the CAD model into a voxels matrix. In this paper is presented a methodology that allowed to exporting objects created in CAD programs into the form of MCNP input files quickly and reliable. With the process were obtained very good results. The shape and size of the voxel model match up very well with the original mesh. The working time required for the setup the 3D animation, export the model and create MCNP input file was lower than an hour using a common PC.

Keywords: dosimetry; computer simulation; anatomic models.

Resumo

Os Modelos Antropomórficos são amplamente utilizados em simulações computacionais para o calculo de fatores de conversão para dosimetria interna e externa. Porém, sua construção é uma tarefa difícil e demorada devido à necessidade da segmentação de imagens de Tomografia Computadorizada (CT). Por outro lado, nos últimos anos novos programas de Desenho com Auxilio de Computador (CAD, Computer Aided Design) têm sido utilizados para desenvolver novos Modelos Antropomórficos baseados em superfícies NURBS (Non Uniform Rational B-Spline), Malhas (MESH) e Polígonos. Entretanto a maioria dos códigos de simulação de transporte de radiação não permite a entrada de geometrias no formato CAD, fazendo necessária a conversão dos modelos CAD em matrizes de voxels. Neste trabalho apresenta-se uma metodologia rápida e confiável que permite exportar objetos criados em programas CAD ao formato de arquivo de entrada do MCNP. Com este procedimento foram obtidos resultados muito satisfatórios. A forma e tamanho do modelo voxelizado coincidiu perfeitamente com o modelo de Malha original. O tempo de trabalho requerido para a montagem da animação 3D, exportar o modelo, e criar o arquivo de entrada para o MCNP foi inferior à uma hora utilizando um computador Desktop comum.

Palavras-chave: dosimetria; simulação por computador; modelos anatômicos.

Introduction

The Monte Carlo simulation is a powerful tool for the studies and predictions of ionizing radiation effects in humans. However, accuracy and precision of results will depend significantly of the human model used in the simulation. The first models were made using mathematical equations of spheres, cylinders, cubes, cones, etc. These models are called: Mathematical models. Even though they were not very realist, their high calculation speed has become one of the most used[1-5].

The development of Computer Tomography, Nuclear Magnetic Resonance, and the images processing allowed the creation of more realistic models. These models were called Anthropomorphic or Tomographic[6-9]. They are composed by a tridimensional matrix of voxels. Those voxels are obtained through the segmentation of different organs in CT or RMI images. The main advantage of these models is the realism, although if it compared with the mathematical models, their complexities delay the calculations and increases the difficulties to make any modification of the geometry.

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In the last years, some papers have presented a new generation of more realistic models made using NURBS, MESH or POLYGON surfaces[10-15]. This generation we will call in this paper as CAD models (Computer Aided Design). The broad use of these surfaces for the graphic computation was extended in the industry, in the cinema, and in the television, because they allow representing very well any kind of objects. The principal advantage of these CAD models is to allow the easy modification of the object geometry in function of time and space. At this way, the use of this model allow to create new standards (phantoms), which can characterize different population groups, or can allow to perform 4D simulations.

Nevertheless, the current simulation codes do not accept yet the output files formats, created with CAD programs (AutoCAD, Rhinoceros, Maya, 3dsMax, Blender, etc). Because of this, it is necessary conversion of the CAD model into a Voxel model, which is well accepted by all the simulation codes. Then, a good conversion process is necessary to obtain a reliable and good quality model.

In this work is summarized one methodology developed by our group to make the quickly conversion of a CAD format in a voxel format, followed by the insertion in a MCNPX input file[16].

Material and methods

The CAD Model

To apply the methodology is necessary to define what will be the model to export. In our case it is possible to work with objects or anthropomorphic models defined by NURBS, MESH, or POLYSURFACES. Unlike other methods, in our case the model can contain all the organs inside it during the conversion. Basically, the conversion process consists in to undertake a temporary animation to produce something like tomographic cuts that can be easily copied and pasted on all objects that make up the model. At this way is obtained a sequence of images, containing all organs present in the model.

In this work was used a MESH of an infant to show the performance of the methodology (see Figure 1a). However, the procedures can be applied in any 3D object.

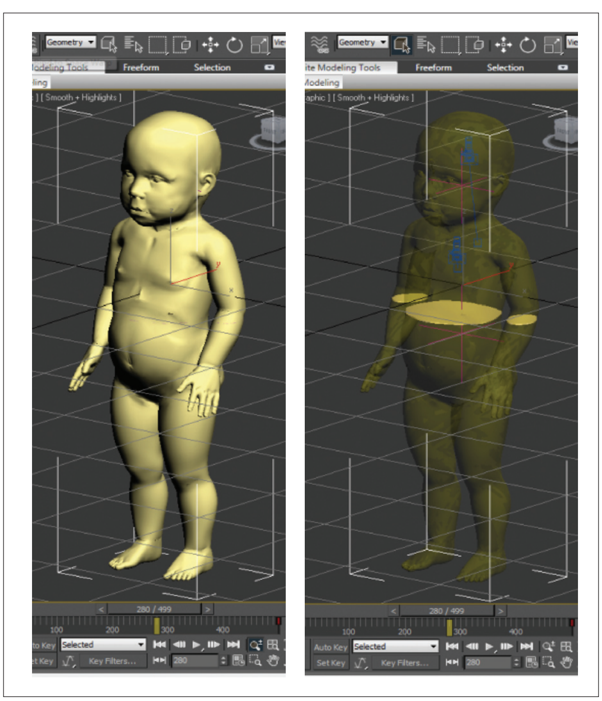

Figure 1. a) 3D visualization of the infant model used. b) Example of an axial cut rendered as BMP image in the top view.

Exporting the Model as BMP Sequence Images

In this work was used the program 3dsMax[17]. This program allows setup animations, defining lights, materials and special effects in 3D objects. In the conversion methodology, first, is necessary to set up an animation and define the number of FRAMES (N) equals to the number of desired cuts, on the Z axis.

Then, is selected one of the organs or parts present in the composition. In this organ is applied the modifier: `SLICE´ to obtain a slice in the form of axial cut. The thickness of this cut can be easily modified. After, in the first frame of the animation, we put SLICE modifier is the Z minimum position (Z_{min}), where the cuts must begin. Then, with the AUTOKEY option enabled, we go to the last frame and put the SLICE modifier in the Z-maximum position (Z_{max}). This make 3dsMax interpolate new axial cuts between position Z_{min} and Z_{max}.

Completed this step, the configured SLICE-modifier can copy and paste to all the objects in the scene or composition. This will generate a sequence of axial cuts, all synchronized in Z. After, the material of each object must be configured to be displayed in the output images with a single color. This will be use for subsequent identification in the MCNP input file. Finally, making a RENDER at the Top View is obtained a sequence of N-images similar to a CT scan. With the definition of the size of the images can be change the output resolution pixels/cm to a desired value.

In this work the animation was configured with 500 frames, obtaining the same number of axial cuts of the model. The values Z_{min}, Z_{max}, and the thick of cuts were: 0 cm, 76 cm and 0.157 cm, respectively. The model body was displayed with in beige (Red=243, Blue=212, Green=164), with average level in 206. The background was left in black (R=B=G=0). The format of output images was 8 bits BMPs, of 320 x 240 pixels and with 0.110 cm/pixels of spatial resolution, totalizing 3.84×10^{7} voxels.

Making the MCNP Input File

To introduce the model and generate the MCNP input file, we use the program TOMO_MC[18] developed by our group. It can read BMP image sequences, generated by all the CAD programs (Figure 2). The TOMO_MC is a program implemented in Delphi 7.0 on the Windows platform. The construction of the input file within the program is divided into three parts. The first is the opening of the model and the definition of materials and densities on their organs. In the second part, is selected the three-dimensional region where the simulation will be carried out. Finally, in the third part is defined the geometry of the source (AP, PA, LLAT, RLAT, ROT or ISO), their particles energy and number of stories. Because the program initially was used to make input files for Radiation Safety calculation in MCNP, in all cases the simulated magnitude is the absorbed energy (F8) in all the organs of the model.

In this paper, to generate the input file was used the images sequence previously obtained with 3dsMax. Once loaded the files, the work region was defined with 320x240x500 voxels. The Voxel dimension was considered as 0.110x0.110x0.157 cm^3. Arbitrarily to the infant body was assigned equivalent materials to soft tissue. To see if a satisfactory model was created, simulations with 1MeV photons were done in AP and PA geometries considering 10^7 histories. The PTRAC option was enabled to analyze the trajectory and interaction of particles

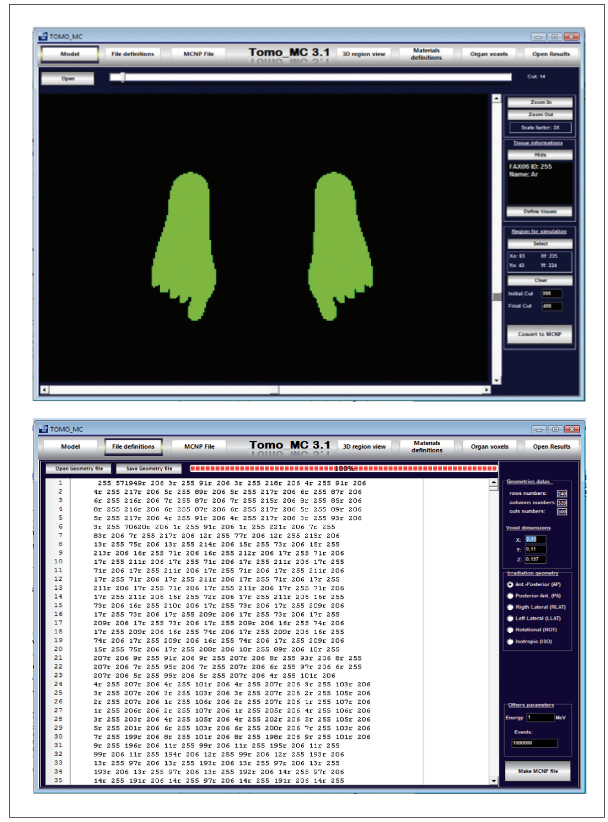

Figure 2. TOMO_MC software for generation of MCNP input files from Voxels Models [18].

Results and discussions

With the presented methodology we convert one infant mesh model into a Voxel model. As a result of this process, was obtained a sequence of 500 images in BMP format of 320x240 pixels (Figure 3). The resolution of images was 8-bit in color scale, which can put more 256 of different objects in a selected palette. This quantity of colors is sufficient to represent any number of materials or tissues in the scene. Nevertheless could be use BMP files with 24-bits that could increase this amount to 16 million.

With the output images, and using the TOMO_MC was created an input file for the MCNP. The time taken to complete the whole process was less than one hour using a 4GB RAM and 2.68 GHz Core2Duo PC.

Simulations using MCNPX 2.6.0 version were done. The Moritz software was used to make a 3D visualization and to check the presence of errors in the input file for MCNP[19]. The 3D view was satisfactory; perfectly in agree with the original MESH model (Figure 4). Moreover, the input file didn't provide any error in its execution. The trajectory of the first 50 particles was displayed to check the position and direction of the source, as well as the physical aspects in the simulation (Figure 4). In all cases, the results agree with those expected.

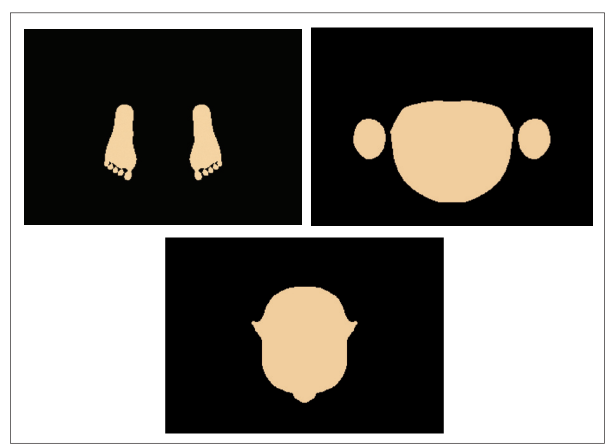

Figure 3. Sample output images in 8bit BMP, showing axial cuts of the model.

Conclusions

In this paper was presented a quickly and optimized methodology, which allows exporting a 3D CAD model as a voxel one, and then introduced it in the MCNP as an input file. In this work, unlike previous methods, all parts of the model are shown in the BMP output image with their colors and their respective locations. This fact reduced the time required to export the model.

Future works intended to use this methodology, and the program of animation 3dsMax, to perform 4D Monte Carlo simulations, which include spatial changes over time, and the use of animals models for simulations in other research areas (Figure 5).

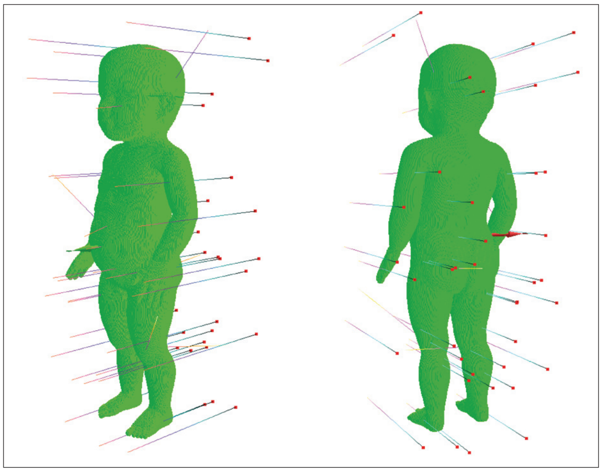

Figure 4. a) 3D visualization of the MCNP Input File geometry. b) Lateral view showing particle tracks resulting from the simulation of fifty 1MeV photons.

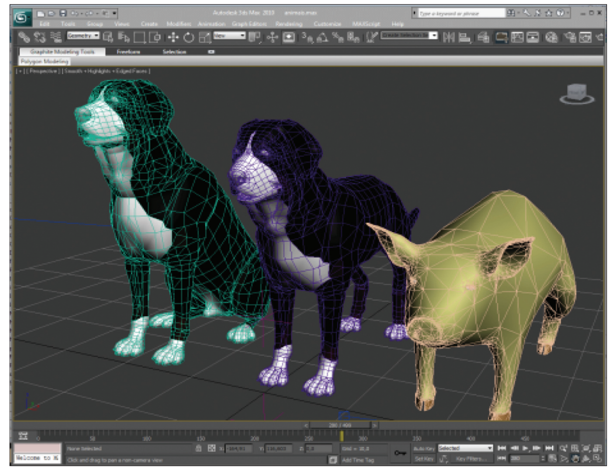

Figure 5. Samples of 3D animals models which can be used in Monte Carlo simulations.

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