STYLIZED vs TOMOGRAPHIC: AN EXPERIENCE AT RPI

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Introduction

Radiation protection dosimetry relies on fluence-to-dose-equivalent conversion coefficients that are affected by three major factors:

1) human anatomy and tissue properties;
   - stylized models that are based on surface equations
   - tomographic models that are based on medical image

2) Monte Carlo code;

3) Algorithms to derive dose quantities.
Stylized Models Developed for MIRD
Had Been the *de facto* Standard for 30 Years

- Stomach
- Small Intestine
- Upper Large Intestine
- Lower Large Intestine
Stylized Pregnant Woman Models

Existing models are crude, simplified shape, size and locations of organs (Stabin’s 1995)

3-month model

6-month model

9-month model
The past decade saw the emergence of a new class of human models called tomographic (or voxel) models.

**The Hypothesis was:**
*The greater realism in anatomical models would improve the radiation dosimetry.*

**Questions remain today:**
- Are dose estimates really improved?
- How much improvement?
- Is it worthy the effort?
Objective of This Presentation

To compare the effective doses from the stylized and two tomographic models for exposures to photons, as well as selected electrons, neutrons and protons.
The Visible Human Project®
- National Library of Medicine


Color Photography
(0.33mm x 0.33mm x 1mm)

Computed Tomography
(1mm x 1mm x 1mm)

Magnetic Resonance Imaging
(4mm x 4mm x 4mm)
Challenges With Tomographic Models

Segmentation is laborious
- At least months or years are needed

Computer Memory
- VIP-Man (0.33mm x 0.33mm x 1mm) is 3.7 GB data set
- The max. allowable RAM is < 2 GB

Monte Carlo Codes
- EGS4 and MCNP4b/MCNPX had to be enhanced for handling such huge voxel data

Computer Timing
- The smaller the voxel size, the longer to run (~several hours)
An adult male whole-body voxel model, called Visible Photographic Man (VIP-Man), has been constructed and adopted for Monte Carlo calculations.


**EGS4**
Photon / Electron
0.286 mm x 0.286 mm x 0.946 mm (scaled voxel size)

**MCNP**
And
**MCNPX**
Photon/Electron/Neutron/Protons
3.45 mm x 3.45 mm x 3.785 mm (scaled voxel size)

Images shown here are plotted from input data in EGS4 and MCNP/X, respectively.
Stylized vs. Tomographic

MIRD Stylized Model

Visible Man

Liver
Stomach
Spleen
Bone
Lungs
Spleen
Esophagus
Method: External Parallel Beams

- Particle types
  - photons, electrons, neutrons and protons
- Energy ranged from 20 keV to 10 GeV
- Standard irradiation geometries (vacuum for electrons)
Results: Effective Dose for Photon Beams

- Data for stylized model were from ICRP 74/ICRU 57
- Above 1 MeV, EDs within 10%
- Between 0.1 –1 MeV, EDs differ within 20%
- Below 0.1 MeV, ED differ up to 80%
Segmentation of Organs for the pregnant woman model (Shi and Xu 2004)

34 organs and tissues have been segmented
The Hypothesis:

The greater realism in anatomical models would improve the radiation dosimetry.

Questions:
- Are dose estimates really improved?
- How much improvement?
- Is it worthy the effort?
Problems with Voxels

- Many internal organs difficult to segment in CT images
- Small structures (e.g., skin, eyes) difficult to model
- Geometric uncertainty and computational tradeoffs inherent to voxel use remain
- Difficult to standardize
- Very difficult to deform

Different voxel sizes show variation in shape
The Future? Advanced Boundary Representation

Deformable Organ Models Using NURBS
Segars et al (2001)

CAD Deformation of Lung

Vol: 317.54 ml

Vol: 211.72 ml
Conclusions

• For external photon, the scaled VIP-Man model does not have practical impact on the radiation protection dosimetry

• Any single tomographic model is not representative enough

• Tomographic models only provide info on anatomical variations

• Future models will have advanced surface representations
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