

Monte Carlo study of a X-ray examination, the basis and the effects of the external radiation shields

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Abstract

Syventävä aineopintojen labra. Eunice-phantomi, annoslaskennan simulointi etc

Keywords

BodyPhantom — Eunice — ImpactMC — Dose map

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Introduction

The radiological examination provides valuable information about the health of the patient and plays an important role in helping a doctor to make an accurate diagnosis. However, such an examination exposes the patient to the radiation, thus

the benefit of the examination and the possible harm of the radiation dose must be cooperatively taken into account at a planning stage.

It has been shown, that the most common and cost-effective examination in conventional radiography is the radiological examination. (Helasvuo 2013, Speets et al. 2006, Veldkamp et al. 2009, McAdams et al, 2006). Still, the effects of the external shields to reduce the dose are yet to be studied. One of possible approaches for such investigation is simulating the situation and combining the produced situational possibilities to investigate the differences.

The most essential part of this approach is the choice of the simulation engine. The ImpactMC software has been shown correctly reproducing the situation (VIITTEET), thus it was selected as a simulation creation tool. In order to avoid the exposure of the patients to the dose, those analysis are done using the Eunice bodyfantom (VIITE). By using the phantom, it is possible to not only simulate the situation, but also to verify the simulation by direct measuring.

The aim of this paper is to step by step describe the process and make a preliminary conclusion about the effect of the external shields to the dose.

Methods

This section is separated into 3 steps:

1. Imaging the phantom and preprocessing
2. ImpactMC simulation
3. Analysis of the results

1. Methods and theory, preprocessing

This section covers all the processing needed to be done before the simulation.

1.1 CT imaging principle

Let's start with the small snap of theory about Computed Tomography (CT) imaging. The CT-imaging bases on ability of X-ray to pass through the object without significant change of the ray direction, and proportional to materia signal weakening. In other words, there are two assumed postulates:

1. X-ray direction doesn't change while passing through the object
2. The X-ray weakening proportionally depends on the density of the passed materia.

Those assumptions result in situation illustrated in Fig. 1

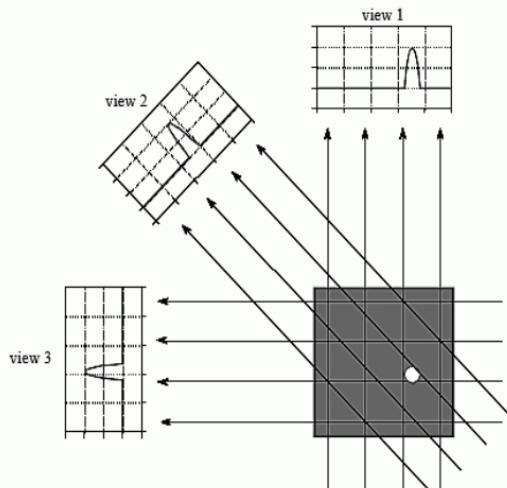


Figure 1. The imaging principle of CT.

The next step is the inverse problem of combining the multiple directional scans into forming the image. The simple version of reconstruction called Backprojection is illustrated in Fig. 2.

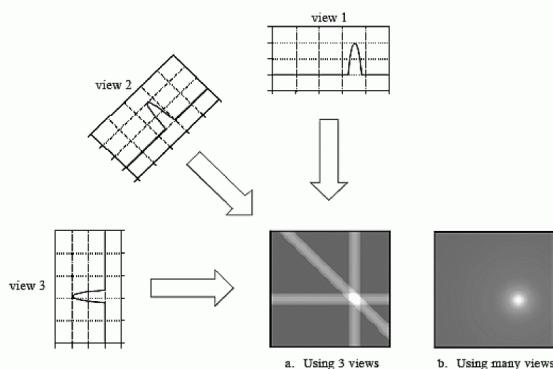


Figure 2. The reconstruction principle of CT.

Nowadays, the reconstruction algorithms are not that simple, there are many filterings applied in order to improve the image quality. In more detail, the reconstruction algorithms are described in the course "Inverse problems" by Samuli Siltanen, Math department at the University of Helsinki.

1.2 Eunice phantom

1.2.1 The structure

The Eunice phantom is a combination of plastic disks with holes for dose measurement wires. (Fig. 3) The consistence of each disk is different and reproduces the organ densities.

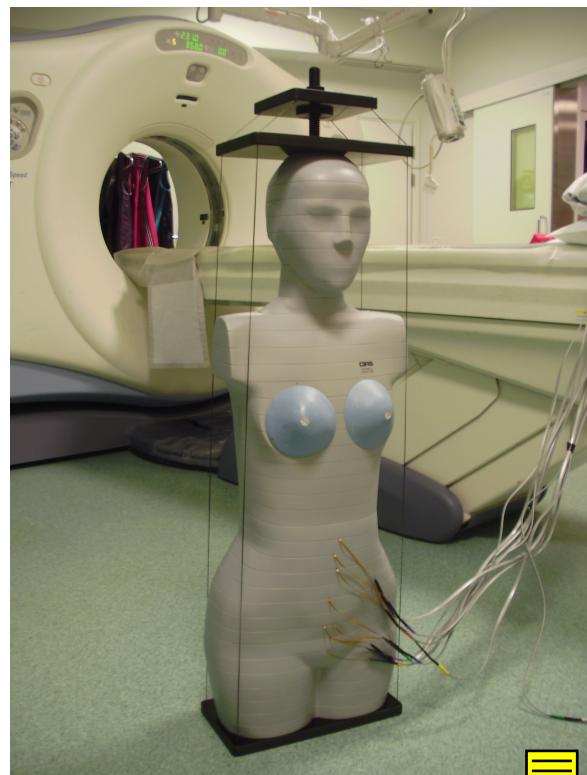


Figure 3. A photo of the Eunice phantom.

1.2.2 In general

The first step is to obtain the image of the object of the investigation, in other words to get a 3D image of the phantom. The best results for the studies are produced at 129kV (Annan viitteet), however at equipment available at HUS, such sequence is not an option. The closest options are 120kV and 140 kV. Thus, for the analysis the 120kV sequence has been chosen.

The obtained image is illustrated in Fig. 4. (Thanks to Timo Paasonen for measurement.) The dimensions of the image are 512-512-377, with voxel size of 1.5625mm-1.5625mm-2.5mm.

1.3 CT imaging direction

The radiation dose effect is tissue dependable (VIITTEET), thus the imaging direction is chosen to be posterior-anterior. (Fig. 5) The benefit of such selection is minimization of the dose to baby or radiotion sensitive organ doses.

1.4 Phantom segmentation from the table

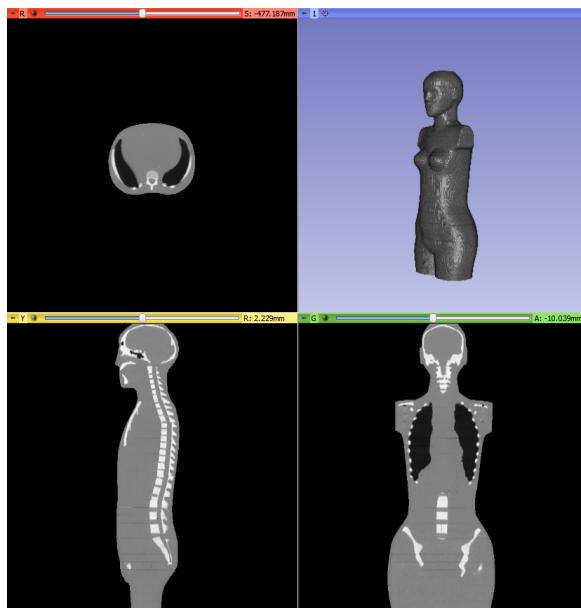


Figure 4. The structure of Eunice phantom visualized as 3D image with axial (red), sagittal (yellow) and coronal (green) slices.



Figure 5. The CT-imaging session.

*Anna, tämän osion voisit kopsata potilaiteesi käsitteilyyn...
Pikahahmotelma suomeksi, note2self: muista kuva jokaiseen*

vaiheeseen:

0. Fantomisarjan lukeminen.
1. Thresholdaus välillä: minimi - -140 / -170 . Tulos tallennetaan niftiksi.
2. Alle puolen kokoisten kappaleiden poisto, invertointi, alle puolen poisto, invertointi. Dilatointi + eroddaus väliin jos ei toimi, kunnes toimii.
3. Maskaus
4. DCM luominen

1.5 Types of external shields

This paper analysis the four types of external shields, based on their height. The Eunice phantom consists of 38 disks, so the types of shields are defined accordingly: A (disks 21-38), B (23-38), C (24-38) and D (25-38). (Fig.6.)

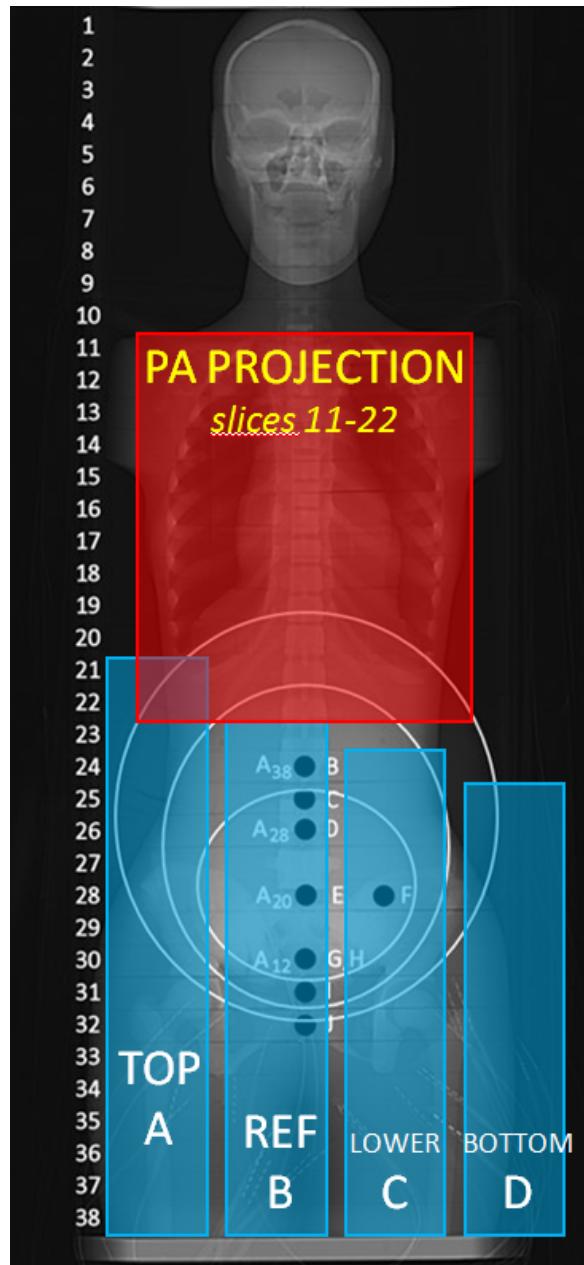


Figure 6. Types of shields

2. Methods and theory, the simulation

The general idea of the simulation is simple:

1. Using spectrum create n-amount of particles

2. Pass them through the object
3. Record the result

However, at a closer look, several questions like "What spectrum?", "How many particles?" and "How do they interact?" arise. This section will try to answer to those questions

2.1 Spectrum

The model for spectrum is obtained from XXXXXX, and its probability density function is illustrated in Fig. 7.



Figure 7. The probability density function of X-ray particles for 120kV energy.

2.2 Number of simulation particles

In the literature, the most common limitation for the simulation is the processing time, not the amount of particles.(VIITTEET) However, such approach is not usable, since it limits the reproducibility on another machine.

For this reason, we evaluated at a range from 10^{e8} to 10^{e11} and observed the results in Fig 8.

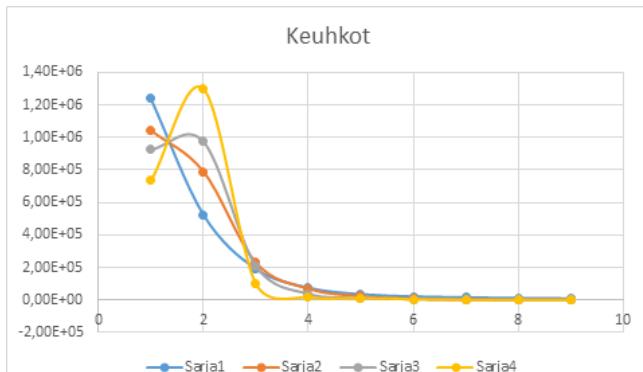


Figure 8. Normalized dose distributions from 10^{e8} to 10^{e11} in the chest... Huom. $1e8, 5e8$, harmaa on $1e9$, kultainen $1e10$.

From this image we can clearly conclude that the structure of the curve doesn't significantly change from the 10^{e9} , thus

2.3 Physics of interaction

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2.4 Step-by-step guide

For some strange reason the GPU version works well only with folders located on the desktop. Thus:

1. Create root folder on desktop (any name) and place all data inside. Especially phantom's dcm-images should be placed inside **Input** folder.

The situation is illustrated in image:

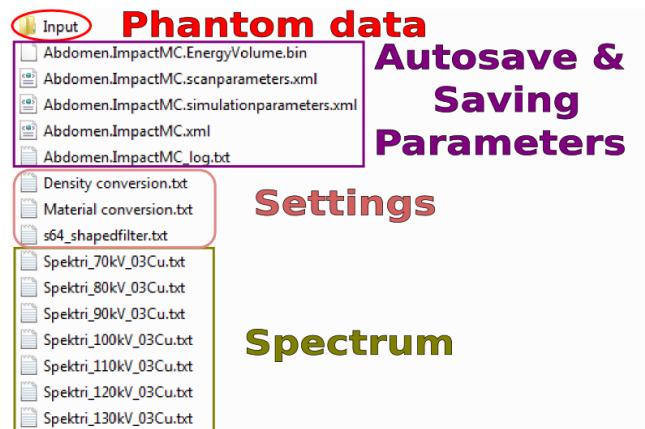


Figure 9. The project root folder locating on the Desktop

The content of Figure 10 can be classified into 4 blocks:

1. The folder with phantom data in dicom format (Red)
2. Saving details
 - This eliminates the need to manually set parameters at each launch.
 - And allows to resume work from the stop point.
3. Settings
 - Density Conversion settings (more detailed described in section **** Methods)
 - Practically since we assume that shield is plumbum, the transformation term into plumbum is added.
 - Material Conversion table
 - shapefilter
4. Spectrum tables for each energy
 - The simulation is meant to be done on several energies

2. Now we can launch the GUI version of ImpactMC.

This graphical user interface consists of 2 blocks: Visualization on the right, and the tabbed parameter setting form on the left. The transfer between MRI image of phantom and dose simulation is performed through the menu options on the top.

Note: This software produces report message about each completed task and tilts in case some action is taken inside it during the simulation, so waiting for the report is highly recommended.

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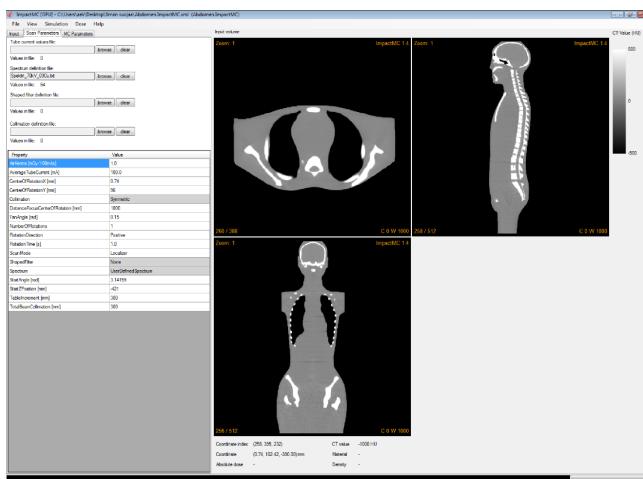


Figure 10. The starting project window

Table 1. First tab of settings

Variable	Parameter
1	4
9	12
13	16

To be continued, kopioi Alexey_labra.doc tänne näistisi.

3. Methods and theory, the analysis

In this section we briefly describe the methodology used in result analysis. The main guidelines of wanted results are the doses in organs and dose distribution maps.

3.1 Organ doses

The first step in calculating organ doses is locating those organs in measured CT image. In this paper it is done manually following the guidelines presented in the Eunice phantom documentation (VIITE).

This doses can be processed in a two way:

1. Histogrammically, as a function of the imaging energy.
2. Volumetrically, as a dose distribution over an organ.

The histogrammical analysis means that every voxel is a measurement point. Basing on the intensities these points can be classified into bins. The produced results are the mean values of the volumes.

The volumetric analysis means that each object is segmented from the context, and investigated separately. Such approach provides more detail information about the organ, and allows to investigate maximal accrued doses in a regions.

3.2 Change of the 3D dosemap according to shield

Another possibility is to analyze the effect of external shields to the dose distribution. This analysis is similar to analysis methods presented in 3.1.

4. Results

The aims of this paper are to illustrate the process, to make some conclusion about external shields effect on dose and to visualize the predicted effect of the increase in the imaging energy on a dose. Current section describes the last two.

4.1 Relative doses

4.1.1 Harmonic mean

Taulukko:

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Table 2. Table of Grades

Name		
First name	Last Name	Grade
John	Doe	7.5
Richard	Miles	2

4.1.2 Histogrammical plots

For example, in chest, the histogrammical approach produces Fig.11.

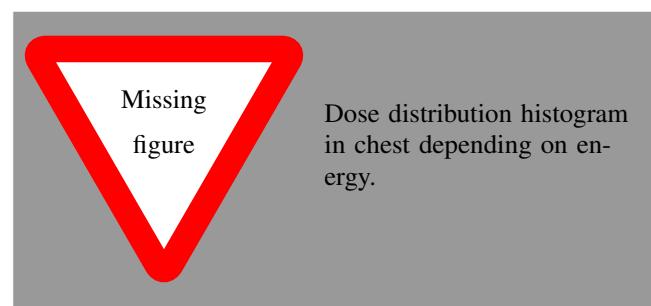


Figure 11. Dose distribution histogram in chest depending on energy.

This figure clearly illustrates that the increase in imaging energy increases the dose. This result is the

Acknowledgments

Attachments

Structure of this paper

Fig.12.



4.1.3 Absolute Dose

5. Discussion

5.0.4 Subsubsection

5.1 Subsection

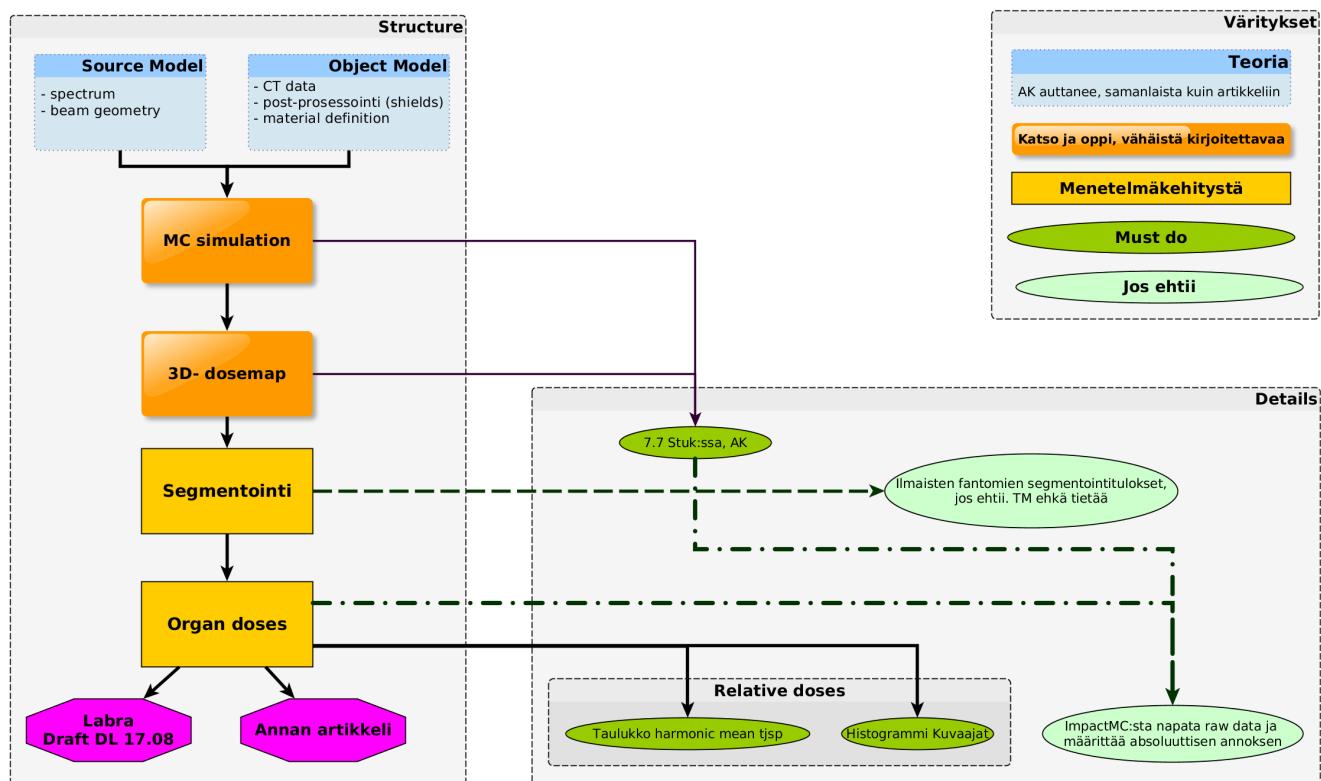


Figure 12. Plan graph