Physikalisch-Technische Bundesanstalt
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Deep learning-based dosimetry in medical x-ray imaging

Type: Postdoc or PhD

Principal Investigators

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Background

In medical x-ray imaging procedures, it is essential to achieve an acceptable image quality at a minimal dose. The measured application-specific dose quantities (ASD) are dose area product (DAP) in general radiography, fluoroscopy and cone beam computed tomography (CBCT) and dose length product (DLP) in conventional CT. These quantities are conceptionally different and cannot easily be converted into each other.

ASD values are the basis for quality assurance and diagnostic reference levels. However, they are not equivalent to patient dose. Patient dose is usually given in terms of organ or effective dose, which are useful quantities for the determination of potential radiation detriments. Conversion factors are needed to obtain patient dose from measured ASD values. They are usually calculated with Monte Carlo methods for reference x-ray devices and a set of mathematical reference patients. Therefore, they are neither machine nor patient specific and introduce large uncertainties.

An increasing number of imaging tasks can be performed with different x-ray imaging modalities, like CT and C-arm CBCT. The comparison of the radiation risk can often only be achieved using patient dose, as the ASD of different modalities are generally not comparable. Direct methods to determine the individual patient dose are therefore highly desirable. Recently, procedures have been developed which allow quick and precise patient and x-ray machine specific dose estimates in conventional CT [1-4]. These are based on deep learning tools which use the CT image of the individual patient to estimate organ doses by simulation of the machine specific CT scan. Comparable tools are not yet available for other x-ray imaging modalities although there is an increasing demand.

Project Aim, Objectives and Program

The aim of the project is to develop and provide procedures for the quick determination of patient dose for medical x-ray imaging procedures. Quick means that the individualized patient dose in terms of organ and/or effective dose is indicated at the display monitor of the medical x-ray device immediately after the imaging process without causing serious delays in the clinical workflow.

The first objective is to develop methods which correlate 2D or 3D patient images with matching mathematical whole-body patient models. These mathematical models are characterized by pre-segmented organs needed for the evaluation of the organ dose. This task can ideally be solved with tools based on deep learning.

The second objective is to develop procedures for quick 3D dose estimates based on simulations of the imaging process using the pre-determined virtual patient model. This task can ideally be solved with the application of the deep dose estimation algorithm developed by Maier et al [4] which are based on a deep convolutional neural network trained by Monte Carlo dose estimates.

The goal of the third objective is the evaluation of the uncertainty and robustness of the algorithm. This will be done by measurements on anthropomorphic phantoms at real x-ray facilities. Several x-ray facilities are present at PTB, others can be used at the sites of our collaboration partners.

Available data

XCAT provides anthropomorphic voxel models with parametrized anatomical sizes. A reference voxel phantom is provided with the ICRP Report 110.

Several databases for medical images are freely available (visceral, LCTSC, Open-Access Medical Image Repositories) and can be used to develop a method for quick 3D dose estimation. In addition, our department maintains contact with various partners such as the Städtisches Klinikum Braunschweig (SKBS), who could provide anonymized image data of patients.

We have several facilities like a CT-scanner and several X-ray tubes on site, and have numerous different ionization chambers, semiconductor detectors and anthropomorphic and reference phantoms which can be used for validation of the method.

Collaboration

- Heidelberg University, Medical Faculty
- German Cancer Research Center (DKFZ) (current collaborations on AI based segmentation of CT datasets and AI based dose calculation for personalized medicine)
- Technical University of Dortmund, Department of Physics (current collaborations on AI based segmentation of CT datasets and AI based dose calculation for personalized medicine)
- Städtisches Klinikum Braunschweig (collaboration within a research project to unify dose parameters in CT and CBCT)

Candidate Requirements

- MSc in physics, medical physics or similar
- Knowledge of a programming language, preferably Python. Experience with Tensorflow, and Keras are beneficial
- Affinity to software development
- Knowledge of Monte-Carlo based radiation transport codes as EGSnrc or Geant4 are beneficial

References

[1] Z. Peng *et al.*, A method of rapid quantification of patient-specific organ doses for CT using deep-learning-based multi-organ segmentation and GPU-accelerated Monte Carlo dose computing. *Medical Physics*. **47**, 2526–2536 (2020).

[2] S. Sharma *et al.*, A real-time Monte Carlo tool for individualized dose estimations in clinical CT. *Physics in Medicine and Biology*. **64** (2019), doi:10.1088/1361-6560/ab467f.

[3] S. Chen *et al.*, Automatic multi-organ segmentation in dual-energy CT (DECT) with dedicated 3D fully convolutional DECT networks. *Medical Physics*. **47**, 552–562 (2020).

[4] J. Maier, E. Eulig, S. Dorn, S. Sawall, M. Kachelrieß, in *2018 IEEE Nuclear Science Symposium and Medical Imaging Conference, NSS/MIC 2018 - Proceedings* (Institute of Electrical and Electronics Engineers Inc., 2018)