Project Title: Accelerating radiation transport simulations in radiation medicine by machine learning

Type: PhD

Principal Investigator

- Dr. Hans Rabus (PTB, SeSc 8.02)

Background

Training, testing and validation of AI methods require large data sets. In particular with regard to AI methods for therapy planning and real-time radiation dosimetry in interventional radiology, measured data on patients is only available to a limited extent for data protection and ethical reasons. In addition, the field of in vivo dosimetry is still in its infancy and in principle only allows point measurements. Synthetic reference data sets obtained using Monte Carlo simulations of radiation transport will therefore be essential for AI procedures in radiation medicine in the future. As was highlighted in several presentations at the recent ESTRO congress (online, Nov 28th -Dec 1st, 2020), synthetic reference data are advantageous, as systematic discrepancies introduced by different protocols for data collection and reporting (“center effects”) are absent. Furthermore, they can, in principle, be produced continuously and at a higher rate than data derived from patients.

While modern Monte Carlo radiation transport codes or toolkits offer the possibility to perform very detailed simulation, the method faces the major drawback that such detailed simulations are very CPU time intensive [1], [2]. The major challenge to be solved is therefore to accelerate the Monte Carlo simulations to quickly generate new data sets in sufficient numbers (for example, if data sets previously used for validation of AI methods have become known).

Project Aim, Objectives and Program

Aim: To enable real-time detailed Monte Carlo simulations.

Objective: Accelerate Monte Carlo simulations by coupling them with machine learning techniques such that intermediate results of the simulation are used to train a neural network. Demonstrating the proof-of-principle for a representative showcase example (to be identified in interaction with clinical partners)

Short description of work program:

- Investigation of possible interfaces between Monte-Carlo (MC) codes for radiation transport simulation and machine learning (ML) methods
- Investigation of the suitability of neural networks for coupling with MC simulations
- Identification of a radiation transport code suitable for coupling with ML methods
- Development of a MC simulation that interacts with a neural network
- Proof-of-principle for a concrete application, e.g. dose calculation in flexible anthropomorphic numerical phantoms

Available data

- not applicable, they will be produced during the project

Collaboration

- Technische Universität Berlin (Prof. Dr. Klaus-Robert Müller)
- German Cancer Research Center (Biophysics in Particle Therapy, Dr. Andrea Mairani)

Candidate Requirements

- MSc in physics (preferential), mathematics, computer science
- Good background in physics
- Experience in one or more of the fields: Radiation transport simulations, Neural networks

References

[1] Javaid U et al. Mitigating inherent noise in Monte Carlo dose distributions using dilated U-Net. Medical Physics 46, 5790–5798 (2019)

[2] Neishabouri A et al. Long short-term memory networks for proton dose calculation in highly heterogeneous tissues. Medical Physics in press, doi: 10.1002/mp.14658 (2021)