Abstract of an oral presentation at the Joint Conference of the ÖGMP, DGMP and SGSMP, Dreiländertagung der Medizinischen Physik, 19.-22. September 2021, Digital Conference. Published in: Dietmar Georg and Wolfgang Birkfellner (eds.), *Abstractband.* ISBN: 978-3-948023-16-4

Expansion of a Small-Animal Proton CT Reconstruction Framework and Studies of Energy Dependence of Relative Stopping Power

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Introduction

We present a reconstruction framework for pre-clinical proton computed tomography (pCT) and investigate the energy dependence of reconstructed relative (to water) stopping power (RSP) for proton energies relevant for small-animal imaging.

Materials and Methods

Proton radiographies were obtained from FLUKA Monte-Carlo (MC) simulations with 75MeV pencil beams using the beamline model of a clinical proton therapy facility. The in-silico detector model consisted of two gas-based tracking detectors, perpendicular to the beam's axis, registering position and direction of individual protons before entering and after exiting the phantom and a time-projection-chamber-based range telescope for residual range measurement. Cylindrical phantoms of various tissue-mimicking materials with different radii varying from 5mm to 20mm were studied. For each phantom, the RSP image of a central slice with 10mm thickness and 0.2×0.2mm2 pixel size was reconstructed, using 180 projections in 2° increments with 106 initial protons per projection scanning along a 4cm field covering the phantom diameter. A total variation superiorization ordered-subset simultaneous algebraic reconstruction technique (TVS-OS-SART) algorithm was implemented in C++. Proton trajectories within the phantom were estimated using straight-line and cubic-spline path models.

Results

Implementation of pCT reconstruction in C++ considerably reduced computation time by a factor of 3 compared to our previous MATLAB-based reconstruction. Mean reconstructed RSP showed minor difference below 0.3% relative to ground truth for all studied materials. A comparison of different cylinder radii has shown that the energy dependence of the RSP is negligible for proton energies relevant for small-animal imaging. Figure 1 shows results for one of the employed materials.

Summary

We developed a small-animal pCT reconstruction code faster than our previous MATLAB-based implementation. Energy dependence of the RSP at low proton energies has shown no substantial impact on the imaging performance.

Supported by ERC grant 725539 (SIRMIO).

Appendix

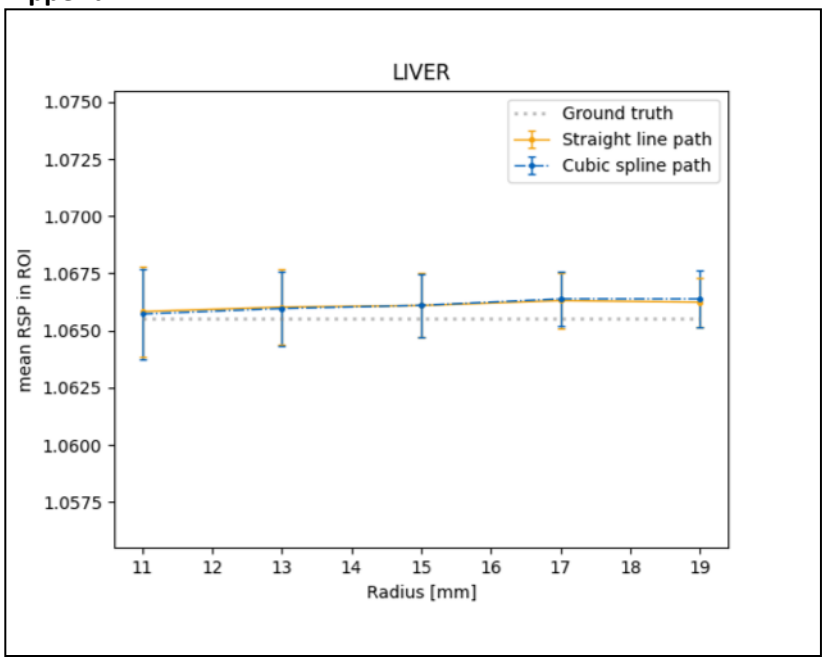

Figure 1: Mean reconstructed RSP of liver cylinders with varying radius.