Inverse-planned fluence field modulation for optimal usage of imaging dose in proton CT

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Abstract

Bowtie filters and tube current modulation are standard procedures for imaging dose reduction in x-ray CT. Despite this, proton CT studies today are performed with an unmodified fluence field resulting in images with inhomogeneous and potentially sub-optimal image noise distributions. Prescribing a specific image noise map may allow for a reduction of dose from image guidance in particle therapy, where good image quality may only be required within the treatment beam path.

We developed a method for fluence-modulated proton CT (FMpCT) to achieve arbitrary image noise prescriptions by exploiting the pencil beam scanning functionality of modern proton centers for fluence modulation. The pencil beam fluence optimization relies on precalculation of object-specific noise maps obtained from a dedicated Monte Carlo simulation modeling characteristics of the phase II pCT prototype scanner and exploiting prior knowledge about the object.

In this contribution we will discuss the accuracy of Monte Carlo simulated noise maps and their agreement to experimental data, including a breakdown of noise into its different sources. Substantial fluctuations of image noise for a pediatric head phantom will be highlighted. Subsequently, details of the iterative pencil beam fluence optimization algorithm will be discussed. Finally, we will report on optimized FMpCT scans yielding constant image noise or low image noise within a region-of-interest shaped like a two-beam IMPT treatment field. Both image noise and imaging dose reduction will be reported.

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