Optimizing Single-Tracker List Mode Proton CT


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Introduction

Precise list mode proton imaging relies on accurate reconstruction of the proton most likely path (MLP) through the patient and requires position sensitive trackers preceding and following the patient. Based on the recently extended MLP formalism by Krah et al. [1], we investigate single-sided proton imaging, i.e. omitting the front trackers and propose a method to optimize the image quality for such a setup. This method involves using the more accurate last half of the path estimation in the image reconstruction and filling up the missing information with an opposing projection.

Path Estimation

It has been shown in Krah et al. [1], that the available treatment planning system (TPS) information (beam spot position/direction, including spot size and beam divergence) can be used in place of a front tracker to compute the MLP. This single tracker MLP lacks the accuracy of double tracker based MLP as seen in figure 2, but by focusing on the more accurate last half of the single tracker MLP we suggest combining two opposing projections.

Monte Carlo Simulations

A single-sided proton imaging setup was simulated using the Geant4-wrapping GATE V8.1.P01 Monte Carlo (MC) toolkit and its built-in modelling method to emulate a generic TPS. Two phantoms were detailed and simulated in order to investigate the effect of the optimization efforts. The first was a 20 cm thick water phantom inserted with five 1x1x1 cm³ aluminium cubes slanted 5 degrees and placed at different depths in order to evaluate the spatial resolution through the phantom. The second was a digitally reconstructed head phantom [2] to test the optimization method on a realistic phantom.

Path Combination

Employing the MLP formalism by Krah et al. [1] in conjunction with the maximum likelihood proton radiography reconstruction formalism by Collins-Fekete et al. [3], we reconstructed radiographies using only the last half of the MLP. By combining two opposite projections we could reconstruct a single radiography based on the two halves of the MLP and thus cover the entirety of the phantom.

Results

Investigating the Modulation Transfer Function (MTF) at 10% for each of the five cubes inside the water phantom we observed an increase in the spatial resolution from 2.4 to 3.4 lp/cm in the front furthest from the remaining rear tracker and from 3.2 to 3.5 lp/cm closest to the rear tracker. Applying the combination method to a more realistic head phantom also revealed a spatial improvement in high contrast regions between dense and less dense materials as observed in figure 5.


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