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Image reconstruction with proton computed tomography

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Objective:
Proton therapy is an emerging approach in cancer treatment. A key challenge is improving the accuracy of Bragg-peak position calculations, which requires more precise relative stopping power (RSP) measurements. Proton computed tomography (pCT) is a promising technique, as it enables imaging under conditions identical to treatment by using the same irradiation device and hadron beam. Our research focuses on developing an advanced image reconstruction algorithm to maximize the performance of pCT systems.

Approach:
A novel image reconstruction algorithm was developed to reconstruct pCT images using measurements of deposited energy, position, and direction of individual protons. The flexibility of an iterative reconstruction method was leveraged to accurately model proton trajectories. Monte Carlo (MC) simulations of CTP528 and CTP404 phantoms were used to evaluate the accuracy of the proposed approach.

Main Results:
For the first time, the iterative Richardson–Lucy algorithm was successfully applied to pCT image reconstruction. An averaged probability density-based approach was introduced for system matrix generation, effectively incorporating uncertainties in proton paths within the patient. Under an idealized detector setup, the method achieved a spatial resolution of 4.34 lp/cm and an average RSP uncertainty of 0.7%. This approach offers a promising balance between accuracy and computational efficiency, with potential for further refinements.

Significance:
This study represents the first application of the Richardson–Lucy iterative algorithm for pCT image reconstruction, demonstrating its viability for enhancing pCT performance.

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