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Tomographic reconstruction from proton CT list-mode data using automatic differentiation

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Proton CT is a promising alternative to X-ray CT for proton therapy treatment planning, allowing direct estimation of the relative stopping power map within the patient body without relying on conversion from Hounsfield units. Conventional list-mode proton CT scanners measure the energy loss of each individual proton to estimate the integral of the relative stopping power along its path, the water-equivalent path length, but do not meet the requirements for clinical use due to their low acquisition rates. An alternative proton CT scanner design was recently proposed where the time-of-flight of each proton is measured between two detectors located before and after the patient along the proton beam. The main advantages of this sandwich time-of-flight design are its compactness and high acquisition rates. However, conversion from sandwich time-of-flight data to water-equivalent path length is not possible. We present an iterative algorithm that leverages PyTorch's automatic differentiation engine to directly optimize the voxels in the image space. The method is assessed and compared using Monte Carlo simulations.

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