A Hybrid Inverse Planning Algorithm of IMPT Optimization

Abstract

Purpose: Although intensity modulated proton therapy (IMPT) is a flexible and powerful treatment technique, its inverse planning can be computationally challenging in terms of memory and speed. Here, we propose a novel optimization algorithm with the hybrid strategy to overcome those challenges. The algorithm worked very well in our tested phantoms and patients.

Methods: A common strategy to speed up the dose calculation during optimization is to use a K_{ij} matrix which stores precalculated dose contributed by the scanning spot j to voxel i. However, this often requires large amount of memory due to the large dose voxel size in patients and multiple energy layers as the extra dimension of data for proton scanning beams. To speed up the dose calculation while keeping the memory usage low, our algorithm separately caches only major dose contributions from scanning spots with full intensities to each dose voxel; the sum of contributions from the remaining scanning spots is cached but unchanged except when they are accurately updated at some specified moment. A lower cut-off threshold can be adjusted to establish the set of spots considered to make major dose contributions. We developed a variant of Newton's method, which automatically determines the patient-customized damping parameter to attain convergence efficiency.

Results: In addition to the greatly improved memory usage by the partial K_{ij}, our tests showed that each iteration is also much faster than that using the full K_{ij} matrix. The algorithm worked well for patients with tumors at different sites, including one with a large tumor in the lung. It showed that significant improvements of critical structure sparing were achieved.

Conclusion: The proposed algorithm was computationally efficient in terms of computing time and memory usage. It worked well in complicated situations involving different treatment sites.