Purpose

We present a full precision large-scale beam angle selection (BAS) framework for IMRT treatment planning. It is developed to assess the clinical impact of different BAS strategies.

Methods:

For more than 400 candidate beam directions, full precision dose calculations are performed on computed tomography data at a 2.62x2.62x2.62 mm3 resolution. The resulting 20–50 GB of dose influence data are distributed on a high performance computer cluster with 10 nodes featuring 12 CPUs each. On this architecture, we can instantaneously combine any subset of candidate beams to a treatment plan. Exploiting parallel programming techniques, we perform full-fledged beamlet weight optimizations by minimization of a quadratic objective function in about three seconds per treatment plan.

In first studies, we

1. derived explicit visualizations of the solution space of the BAS problem, and
2. compared a BAS heuristic with an iterative strategy, a genetic algorithm, and simulated annealing.

Results:

1. For three intracranial cases, treatment plans featuring five beams were investigated. Three beams were fixed at 0°, 120°, and 240°. The remaining two beams were varied in 5° increments yielding 2628 treatment plans. The resulting objective function landscapes are descriptive visualizations of the nonconvexity of the BAS problem.
2. In comparison to standard beam configurations, the genetic algorithm, the iterative strategy and simulated annealing yielded improved treatment plans with a reduced number of beams for three intracranial cases. The genetic algorithm exhibited the best convergence properties. The heuristic BAS strategy also provided beneficial treatment plans at a lower computational cost.

Conclusions:

We developed a powerful tool to compare different BAS strategies. We confirmed the non-convex nature of the BAS problem and showed that genetic algorithms outperform simulated annealing and iterative strategies for our implementations. We demonstrated that smart BAS heuristics may be a valuable alternative for clinical application.