AbstractID: 3314 Title: Fast nonlinear optimization with simple bounds for IMRT planning

Purpose:
The advent of image-guided adaptive conformal radiotherapy demands the development of very efficient methods of intensity modulated radiation therapy (IMRT) fluence map optimization (FMO). To enable adaptive image guidance with daily IMRT optimization the ability to generate high quality treatment plans "on-the-fly" to correct for changes in patient anatomy during the course of radiotherapy is needed. To this end, we have tested the feasibility of employing analytic convex nonlinear objective functions in a FMO model with simple nonnegative bounds on beamlet fluence.

Method and Materials:
The nonlinear FMO model is based on previously studied voxel-based dose-penalty functions that were approximated in linear and quadratic programming models. Well-known gradient and quasi-Newton algorithms were employed along with an Armijo line search that requires sufficient objective function decrease. A simple projected-direction interior-point method was used to enforce fluence non-negativity. The algorithms were implemented in an in-house treatment-planning system. We tested the following methods: steepest-descent, BFGS, symmetric-rank-1, and combinations thereof. The algorithms were applied to 10 head-and-neck cases. The numbers of beamlets were between 900 and 2,100 with a 3-mm isotropic dose grid.

Results:
The tested methods were all found to be at least as fast as a commercial linear and quadratic programming solver (CPLEX, ILog, Inc.). While no single method was best for all cases, the steepest-descent method typically converged the fastest.

Conclusion:
Nonlinear optimization methods can efficiently solve the IMRT FMO problem in well under a minute with high quality for clinical cases. A simple steepest-descent algorithm was highly successful when combined with methods to enforce simple bounds and to perform a robust line search. Quasi-Newton methods have been successful in solving many large-scale nonlinear programming problems, but provide little advantage for the IMRT FMO problem. In the future, we will test the algorithm's robustness with a larger population of cases.