AbstractID: 5659 Title: Performance Evaluations of a Preemptive Approach in IMRT Planning

Purpose:
Preemptive Goal Programming (PGP) facilitates the use of soft-constraints in a hierarchical manner for solving complex inverse planning problems. It is a highly effective multicriteria strategy for IMRT planning. However, in order to ensure good numerical performance, a robust constrained optimization algorithm with a practical strategy for handling degeneracy is required. This study identifies cases when PGP introduces challenging problems that do not hold a conventional constraint qualification. Numerical performance for such problems is evaluated using nonlinear planning metrics (DVH, EUD, and NTCP).

Method and Materials:
PGP, as implemented in our in-house planning system, solves a series of nonlinear least-squares problems by a sequential quadratic programming (SQP) algorithm provided with precise Jacobians by an automatic differentiation algorithm. In the presence of constraint degeneracy, an elastic mode (feasibility bound relaxation) is used to ensure a positive step taken at all iterations. Dosimetric as well as numerical performance is evaluated for dose (or EUD) escalation cases with critical organ dose constraints. Reformulation of constraints is also studied as a potential way of reducing degeneracy in these problems.

Results:
Optimization levels involving strongly active constraints showed degeneracy near optimality, thus requiring use of the elastic mode for convergence. This mode exhibited robust convergence (typically <~100 iterations) for all IMRT cases studied. Highly nonlinear models (NTCP or EUD with high +/-powers) were handled well by SQP. A strategy of constraint reformulation showed a monotonic decrease in merit function value and its dosimetric performances were comparable to those without reformulation.

Conclusion:
The optimization task of escalating target dose is limited by binding dose constraints of OARs, which can also create degeneracy in PGP. This study shows SQP with an elastic mode exhibits a stable convergence using the dose-volume, EUD and NTCP metrics. Numerical performances can be further stabilized by reformulating degenerate constraints.