PhD Thesis title: 'Multicriteria optimization for managing tradeoffs in radiation therapy treatment planning'

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ABSTRACT:

Treatment planning for radiation therapy inherently involves tradeoffs, such as between tumor control and normal tissue sparing, between time-efficiency and dose quality, and between nominal plan quality and robustness. The purpose of this thesis is to develop methods that can facilitate decision making related to such tradeoffs. The main focus of the thesis is on multicriteria optimization methods where a representative set of treatment plans are first calculated and the most appropriate plan contained in this representation then selected by the treatment planner through continuous interpolation between the precalculated alternatives. These alternatives constitute a subset of the set of Pareto optimal plans, meaning plans such that no criterion can be improved without a sacrifice in another.

Approximation of Pareto optimal sets is first studied with respect to fluence map optimization for intensity-modulated radiation therapy. The approximation error of a discrete representation is minimized by calculation of points one at the time at the location where the distance between an inner and outer approximation of the Pareto set currently attains its maximum. A technique for calculating this distance that is orders of magnitude more efficient than the best previous method is presented. A generalization to distributed computational environments is also proposed.

Approximation of Pareto optimal sets is also considered with respect to direct machine parameter optimization. Optimization of this form is used to calculate representations where any interpolated treatment plan is directly deliverable. The fact that finite representations of Pareto optimal sets have approximation errors with respect to Pareto optimality is addressed by a technique that removes these errors by a projection onto the exact Pareto set. Projections are also studied subject to constraints that prevent the dose-volume histogram from deteriorating.

Multicriteria optimization is extended to treatment planning for volumetric-modulated arc therapy and intensity-modulated proton therapy. Proton therapy plans that are robust against geometric errors are calculated by optimization of the worst case outcome. The theory for multicriteria optimization is extended to

accommodate this formulation. Worst case optimization is shown to be preferable to a previous more conservative method that also protects against uncertainties which cannot be realized in practice.

References to author publications that relate specifically to the dissertation:

1. R Bokrantz and A Forsgren, “An algorithm for approximating convex Pareto surfaces based on dual techniques,” *INFORMS Journal on Computing* 25(2): 377-393, 2013.
2. R Bokrantz, ”Multicriteria optimization for volumetric-modulated arc therapy by decomposition into a fluence-based relaxation and a segment weight-based restriction,” *Medical Physics* 39(11): 6712-6724, 2012.
3. R Bokrantz and K Miettinen, ”Improved plan quality in multicriteria radiation therapy optimization by projections onto the Pareto surface,” Technical report TRITA-MAT-2012-OS4, Department of Mathematics, KTH Royal Institute of Technology, 2012.
4. R Bokrantz, ”Distributed approximation of Pareto surfaces in multicriteria radiation therapy treatment planning,” Physics in Medicine and Biology 58(11): 3501-3516, 2013.
5. A Fredriksson and R Bokrantz, “Deliverable navigation for multicriteria intensity-modulated radiation therapy planning by combining shared and individual apertures,” Technical report TRITA-MAT-2013-OS4, Department of Mathematics, KTH Royal Institute of Technology, 2013.
6. R Bokrantz and A Fredriksson, ”Controlling robustness and conservativeness in multicriteria intensity-modulated proton therapy optimization under uncertainty” Technical report TRITA-MAT-2013-OS5, Department of Mathematics, KTH Royal Institute of Technology, 2013.