Optimization of brachytherapy treatment planning using adjoint functions

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The adjoint approach commonly used in nuclear reactor applications is employed in radiation therapy treatment planning. For this work, we define the adjoint function for a region of interest (ROI) as the sensitivity of the average dose in the ROI to a source placement. We investigate an implementation of this adjoint function for optimization of brachytherapy treatment planning. The purpose of this study is to develop an efficient optimization algorithm.

This study specifically focuses on prostate permanent seed implants. The goal of an optimization process for prostate implants is to find a seed configuration that delivers a desired dose to the target while sparing the critical structures.

The adjoint functions are combined in one format, or combined into a single metric, which is the adjoint ratio. The adjoint ratio is the ratio of the adjoint functions of critical structures to the adjoint function of the target. This adjoint ratio as a function of source positions can provide a ranking of source positions based on their ability to achieve the optimization goal.

As an optimization tool, we propose the greedy heuristic, which makes a decision at each step and does not revise the decision in subsequent steps. The greedy heuristic constructs a seed configuration by selecting a source based on the adjoint ratio. Constraints are applied to support this seed selection procedure.

The results prove that the adjoint approach provides a framework for the development of an efficient optimization algorithm for radiation therapy treatment planning.