On the Use of Second Derivatives in Optimization of Radiation Therapy

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The goal of external-beam radiation therapy of cancer is to obtain an acceptable balance between tumor control and complications to the normal tissue surrounding the tumor. During the last decade, the field has experienced a rapid progress. New technology has improved the accuracy of the beam delivery significantly. Together with the development of faster computers, this has led the way for so called 'intensity modulated radiation therapy' (IMRT).

In IMRT, the clinician specifies certain characteristics of the desired dose distribution by introducing objective functions for the tumor and for the critical organs close to the tumor. A discretization of the incident beams and of the treatment volume of the patient is performed and an optimization problem is formulated. In general, the IMRT problem is large-scale and has a non-convex nature, often with linear and non-linear constraints.

In this study we investigate how the Hessian affects the optimization performance for a quasi-Newton algorithm used in a commercial treatment planning system. Currently, the initial Hessian fed into the algorithm is diagonal. The influence of including more accurate curvature information, represented as off-diagonal elements, is explored for three patient cases.

A more accurate initial Hessian results in a much faster progress of optimization than when using a diagonal initial Hessian. Furthermore, the optimal beam profiles differ significantly, with an accurate Hessian they are very jagged compared to the smooth profiles obtained with a diagonal Hessian. Jagged profiles are, in general, not desirable since they are harder to deliver, but for a certain class of IMRT problems they are preferable. The results also indicate that the IMRT problem is an ill-posed inverse problem in the sense that very different fluence profiles can produce almost identical dose distributions.