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Adaptive Methods for Interfractional Motion Mitigation in Scanned Ion Beam Therapy

Promotionsfach: Radiologie
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Particle therapy has been proven to be an effective option for several tumor types (Durante & Loeffler, 2010) (Schardt & Elsässer, 2010) (Schulz-Ertner & Tsujii, 2007). Treatment with scanned ion beam is able to provide more conformal dose distribution compared to conventional radiotherapy. Nevertheless, it is more susceptible to uncertainties such as setup errors and organ motions (Unkelbach, Chan, & Bortfeld, 2007) (Bert, Grözinger, & Rietzel, 2008) (Rietzel & Bert, 2010). In this study, several adaptive techniques are proposed for interfractional motion mitigation, and are tested in the retrospective treatment planning studies using datasets of prostate cancer patient.

Firstly, a ‘plan of the day’ adaptation method based on image similarity is brought out. A daily plan is chosen from a pre-optimized plan library by similarity comparison between a daily CT scan and the planning images. Several similarity measures are tested and the optimum one is identified. To reduce the preparation time for the plan library before a treatment course starts, an ‘extended treatment plan library’ workflow is studied further. Only one original plan is optimized beforehand, and a library is formed gradually by adding plans optimized on daily verification scans after each fraction. Moreover, a PTV generated on multiple images is proposed taking patient-specific motions of not only the target but also the OARs into consideration. The results show that based on the optimum similarity measure, most of the daily chosen plans are able to provide satisfactory if not the best dose distribution compared to other plans in a library and are superior to using repositioning only. The daily plans optimized on the proposed patient-specific PTV provide excellent target coverage and comparable dose to the OARs as compared to daily plans optimized on the PTV of a single prostate volume.

Furthermore, to track the exact interfractional target motion, a fast plan adaptation method which has the potential for online replanning is introduced. Analysis of optimized scanned ion beam plans indicates that the particle number modulation of consecutive rasterspots in depth shows little variation throughout convex target volumes. Thus, a depth-modulation feature can be extracted from optimized plans and adapted for new plan generation. The proposed method is tested with the prostate cancer patient and digital phantoms datasets. Generally in one minute on a standard PC, the plan can be generated based on either absorbed dose or biologically effective dose, providing excellent dose distribution and is comparable to the optimized plans.

Part of the results have been published and patented, which are listed in the appendix 1.

Works Cited in the Abstract

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