An automated replanning strategy for near real-time adaptive proton therapy

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Purpose:
To develop a method to automatically adapt treatment plans in near real-time to the anatomy-of-the-day for prostate and cervical cancer.

Material/Methods:
Starting point is a prior plan optimized on the planning CT. First, spot positions (Bragg peaks) from the prior plan are restored by adjusting the energy of each pencil-beam to the water-equivalent path length in the daily CT. Subsequently, to compensate for deformations of target and OARs, pencil-beams are added followed by a pencil-beam weight optimization using the Reference-Point-Method. This method generates a Pareto optimal plan for the anatomy-of-the-day, with similar trade-offs to those in the prior plan. The method was evaluated using 8-10 daily CTs of 11 prostate cancer patients (88 CTs) and 3-4 daily CTs of 5 cervical cancer patients (19 CTs). Evaluation was done by comparing for each CT a full multi-criteria optimization without time constraints (benchmark) to the proposed method and to a forward dose calculation of the prior plan on each CT (no replanning).

Results:
The figures show large dosimetric differences between no replanning and benchmark, while the differences between the proposed method and benchmark are substantially smaller. The use of replanning improved target coverage to clinically acceptable levels in 85/88 CTs and 19/19 CTs for prostate and cervix, respectively. All plans showed reduced OAR doses. Replanning took on average 2.9 and 3.6 minutes for prostate and cervix, respectively, using ~50% for dose computation.

Conclusions:
The automation and realized replanning times make the proposed method an important step towards real-time adaptive proton therapy.

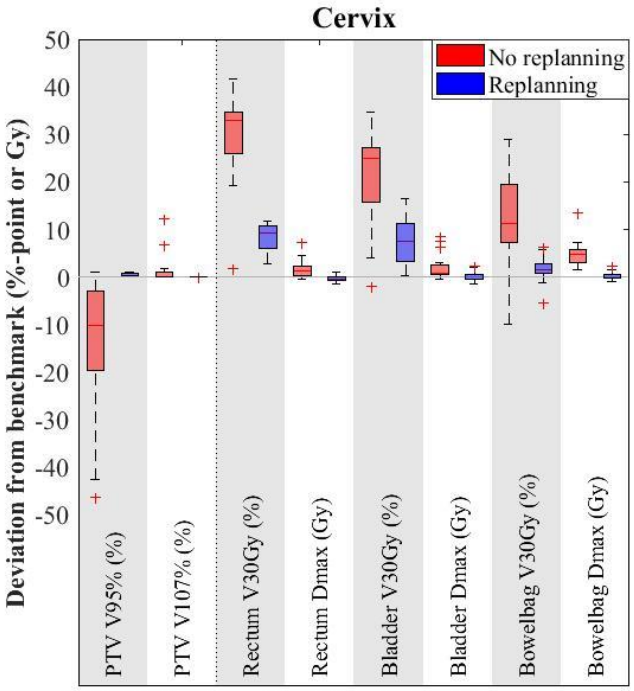

Figure 1. Dosimetric differences between no replanning and benchmark in red and between replanning and benchmark in blue, for the 19 cervix CTs. Differences closer to 0 correspond to better results.

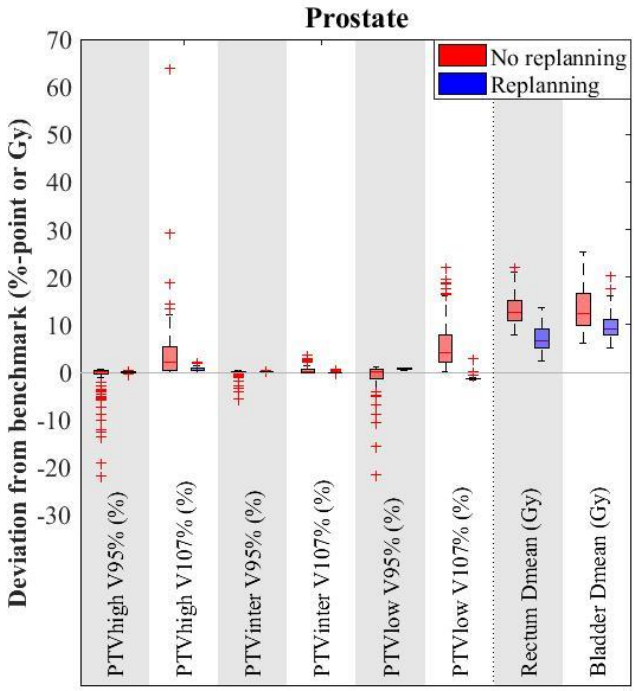

Figure 2. Dosimetric differences between no replanning and benchmark in red and between replanning and benchmark in blue, for the 88 prostate CTs. Differences closer to 0 correspond to better results.