Towards Automated Treatment Planning in Radiotherapy

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Introduction

Treatment plan optimization is a labour-intensive time-consuming task, with quality highly dependent on the skills and experience of the planner. The high-complexity of the problem may often result in suboptimal plans.

The aim of this PhD was to develop an algorithm for fully automated treatment planning, including integrated beam angle selection and integrated IMRT optimization, with higher plan quality than contemporary plans. This lead to the Erasmus-iCycle algorithm.

Clinical Workflow

- Erasmus-iCycle selects wish-list
- Technician on cluster computes plans
- Physician checks final treatment plan
- Clinical TPS reconstructs plan

Conclusion

Treated over 800 patients since 2010, with 500 in 2013!

Erasmus-iCycle allows to:
- automatically generate treatment plans, with quality generally superior to plans made by dosimetrist and physicists.
- perform large-scale treatment-planning studies, comparing treatment strategies.
- further personalize treatment by selecting the best modality on a per-patient basis.

Automated Multi-Criteria Optimization

The basis of automating treatment planning lies in automating the decision-making. By a priori defining constraints and prioritized treatment objectives, a so-called wish-list can be constructed. The objectives are sequentially optimized, resulting in a relevant Pareto-optimal solution without interaction.

No per-patient tuning is required, so a single wish-list can be used for a group of patients. The same list is used for fixed-beam setup, beam angle optimization and VMAT.

Prospective Study

Erasmus-iCycle was clinically introduced after a prospective clinical study. In 97% of the plans, the physician preferred the automatically generated plan above the manual.

Differences in OAR mean doses, where positive values are in favour for the automated plans. For patient 11, target coverage was not attained in the manual plan, but was in the automated plan.

Personalized Treatment

Further individualization of radiotherapy is possible by generating for each patient plans for multiple modalities and settings, e.g. coplanar and non-coplanar 7, 9, 11, ... beams plan, VMAT, IMPT, CyberKnife, etc., rather than a priori specified by protocol. The patient is then treated with the most optimal individual configuration.

Planning Studies

The deterministic nature of Erasmus-iCycle allows objective treatment planning studies. As there is no planner variation, different strategies are easily tested on a large group.

Studies already performed included 1) the impact of the absence of posterior directions for the CyberKnife for prostate cancer (left), 2) prostate patients metal hip prostheses (right), 3) coplanar vs. non-coplanar, and 4) online re-planning for liver SBRT.

Convergence with number of beams, relative to the 10 beam coplanar plan (blue). Colours indicate different degrees of freedom in beam orientation. Blue = coplanar, Green is conventional CyberKnife positions, Purple fully non-coplanar. Red and Cyan extended CyberKnife node sets.

Improvement over contemporary practice for prostate cancer patients with bilateral hip prostheses, where beams passing through a prosthesis are removed completely. Cutting the IMRT field instead leads to much improved sparing (blue), while a non-coplanar removal technique (red) is only marginally better.