Abstract

The main challenge of radiation therapy is delivering sufficient radiation dose to target, while minimizing irradiation of healthy tissues in the presence of uncertainties. Current radiotherapy guidelines, based on ICRU reports, recommend accounting for these uncertainties using target volume expansion by margins. While this approach is historically sensible, it oversimplifies much of the complexity exhibited by tumors and limits more complex dose planning made possible by the advancements in technology over the last decades.

In this thesis we present an alternative approach – a probabilistic incorporation of uncertainties in radiotherapy. In this approach that we call “probabilistic target definition and planning” (PTP), uncertainties are not accounted for using target expansion by volume, as is done in the classical GTV-CTV-PTV approach. Rather, probabilistic target volumes are used to capture microscopic disease presence uncertainties, and robust optimization is used to account for treatment delivery uncertainties.

To evaluate the viability of this approach, we implemented PTP in the in-house TomoTherapy treatment planning system WiscPlan and applied it on realistic examples to evaluate its feasibility. We performed example quantification of imaging uncertainties using test-retest repeatability analysis on a dataset of patients with glioblastoma imaged with FET PET/CT, used it to derive voxel-level target maps and directly implement them in the PTP treatment optimization.

To evaluate the ability of the PTP approach to optimize non-uniform dose prescriptions, we expanded the analysis to a dataset of patients with prostate cancer imaged with multiparametric MRI, where we performed a quantitative comparison between classical and PTP planning. Finally, we applied the method to different disease sites, each faced with its own challenges, and evaluated the performance of their dose plans.

PTP achieved comparable performance to the classical approach, but with significant improvements observed for some treatment sites. PTP also allows incorporation of probabilistic normal tissue descriptions and dose-painting-by-numbers optimizations under uncertainty.

The work presented in this thesis presents a novel treatment planning approach, which endeavors to be an alternative, more flexible method to optimize external beam photon dose plans by removing the limitation of margins and by directly implementing patient's disease information in treatment plan optimization.