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MASTER THESIS Optimization of Radiotherapy Treatment Plans Based on Monte Carlo Dose Computations
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Advancing Radiotherapy Treatment With the Accuracy of Monte Carlo

POPULAR SCIENTIFIC SUMMARY **Ludvig Håkansson**

Accurately computing the dose in the body is important to be able to deliver a good treatment to cancer patients. This thesis has investigated the feasibility to use the most accurate such, based on the statistical method Monte Carlo.

Treatment planning, the process of finding good machine parameters through the means of mathematical optimization, plays a vital role in providing good treatment to cancer patients. In order to reach an adequate treatment plan, the algorithm used for simulating the dose in the patient must model the reality well. The most accurate algorithm for this is the Monte Carlo method, which in the context of radiotherapy treatment most often is used for pre-computing spot doses and optimizing the intensity for each spot. This method is hard to expand to other treatment types mainly due to two reasons:

- storage limitations on the treatment planning machine makes it unfeasible for treatment types that uses more spots, and
- the method only works when the dose in the target is linear to the parameters, which is not the case for photon treatment.

Because of this, it would be preferred to not store the mentioned spot doses and instead perform the computations during the optimization. This, however, makes the optimization problem non-convex due to the statistical noise introduced by Monte Carlo.

This thesis investigates the feasibility of using first-order optimization methods for treatment planning based on Monte Carlo simulations and addresses the challenges posed by the noise. A simplified proton Monte Carlo dose engine was implemented together with a matching analytical such, in order to assess the effect of the noise during optimization.

The results demonstrate that despite the noise, an adequate treatment plan can be achieved. Convergence is found to be dependent on how one spends the simulation "budget". Techniques such as accumulating total dose and computing the gradient and Hessian separately show promise for improving convergence and time efficiency, respectively. The impact of noise on error computation and the need for appropriate comparisons are highlighted.

This work provides insights for advancing Monte Carlo based treatment planning and its integration into clinical settings. The findings are applicable not only to proton treatment planning but also to types such as other ions and perhaps even photons.