Collaborative Research: Tumor and Organs at Risk Motion: An Opportunity for Better DMLC IMRT Delivery Systems

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The main research activity of the project is to develop theory, algorithms, implementations and simulations for radiation therapy treatment delivery with moving target, aiming to take advantage of tumor movement to improve treatment delivery. The PIs and their students have partially developed software to visualize dose accumulation to target and healthy organs for treatment delivery simulations, including the static case, target only motion in 1D and 2D, and dynamic target and organs at risk motion. Work has also commenced on mapping 4D treatment planning algorithms for reproducible motions of body anatomy to NVIDIA GPUs, using CUDA.

The effective delivery of various radiation therapy procedures requires fast motion of the gantry around the patient lying on the treatment couch and often fast change of speed of gantry in its angular motion. However, the gantry of linear accelerator is also characterized by large inertia and changes in gantry angular speed have to be limited due to mechanical restrictions. Existing delivery systems, due to mechanical limitations, are restraining the angular acceleration of the gantry. Nevertheless, in all descriptions of existing deliveries the gantry acceleration constraints are not explicitly included as delivery limitations. It is only left for readers to recognize that omitting these constraints may lead to suboptimal delivery efficiency or sacrifice the integrity of the plan. In cases of delivery of VMAT arc therapy to static anatomy the optimal efficiency solution taking into account the desirable gantry angular acceleration constraint is relatively straightforward to impose and can be implemented without considerable modification of existing strategies. Moreover, the increase in time of delivery caused by this additional limitation in the delivery strategy is modest.

The situation of implementing constraints is considerably more involved in case of moving anatomy. By moving anatomy, we understand here the case when the motion of the irradiated target is defined before treatment is initiated. In other words, we consider here the situation where we are able to register the periodic motion of patient organs (target) at some time before treatment, and assume that this motion pattern is repeated during therapy delivery. In such situation it is not too difficult to realize that the interaction of gantry motion with characteristics of the motion of the target in the BEV plane at given gantry angle will take place. It is evident that constraining acceleration during gantry motion will influence the time when the gantry reaches a given position and the speed of target motion in BEV plane at that angle. This speed of target in BEV plane will then directly influence the maximum speed of motion of MLC leaves relative to the target.

The PIs have developed a solution to the problem of optimal efficiency delivery of VMAT arc therapy to moving targets that takes into account limitations of gantry acceleration. Our approach is gradual. We first applied our methodology to the simpler case of static target delivery where other methods of solution work as well. We compared these deliveries with the general methodology developed in this work to validate the approach legitimacy. We then applied our method to cases when simpler methods of solution do not apply. The indispensable requirement fore these deliveries is the condition that solutions preserve dose distributions as calculated by the plan. The factor that differentiates between more or less desirable deliveries is the over all time of the therapy delivery. This parameter is therefore calculated for each admissible solution that takes into account acceleration constraints that are imposed.