A Network-Flow Solution Approach to VMAT Treatment Plan Optimization

Background: We consider a two-stage method to VMAT planning, the-so-called VMERGE, introduced in [1]. To improve the delivery efficiency of the plan, VMERGE iteratively merges pairs of neighboring arcs using a greedy heuristic approach and delivers the sum of the fluence maps over the combined arcs. However, this comes at the expense of dose quality deterioration so that there is a trade-off between the two. Hence, to obtain the desired tradeoff we formulate and solve an optimization problem, which we call the merging problem, where the goal is to find the optimal merging of the beam angles so that on the one hand the delivery efficiency of the treatment plan is improved and on the other hand the dose quality does not substantially deteriorate.

Solution Approach: We construct a network model where there is a one-to-one correspondence between the source-to-sink paths in the network and all possible merging patterns (see Figure 1).

![Figure 1: The network model for the merging problem where nodes represent the initial beam angles as well as the starting MLC leaf position at that angle (−, + denote the left and right side of the field) and arcs show all possible merges.](image)

We then model the merging problem as a bi-criteria network-flow problem to find the path that on the one hand has the minimal treatment time and on the hand has the minimal deviation from the initial dose distribution. Moreover, we apply several heuristics to the merging problem and contrast their trade-off curves against the Pareto approximation (see Figure 2).

![Figure 2: (a) Trade-off curves obtained by merging heuristics against the Pareto-frontier approximation. (b) DVH curves associated with the initial plan (solid), Pareto-optimal merged plan at treatment time of 150 seconds (dashed) and a heuristic merged plan with a similar treatment time (dotted).](image)