

New Algorithms for Target Delineation and Radiation Delivery in Intensity-Modulated Radiation Therapy

Intensity modulated radiation therapy (IMRT) is a modern cancer therapy technique that aims to deliver a highly conformal radiation dose to a target tumor while sparing the surrounding normal tissues. The prescribed dose is specified by an intensity map (IM) matrix and often delivered by a multileaf collimator (MLC).

In this thesis, we study a set of combinatorial optimization problems arising in the field of IMRT: 1) the auto-contouring problems using region properties, which aim to optimize the intraclass variance of the target objects; 2) the field decomposition problems, whose goal is to decompose a "complex" IM to the sum of two "simpler" sub-IMs such that the two sub-IMs are delivered in orthogonal directions to improve the delivery efficiency; 3) the field splitting problems, which seek to split a large IM that can not be directly delivered by MLC into several separate sub-IMs of size no larger than the given MLC size and the delivery effectiveness is optimized.

Our algorithms are based on combinatorial techniques -- mostly graph-based algorithms. We strive to find the globally optimal solution efficiently -- in a linear or low polynomial time. In the case that the exact algorithm is not efficient enough, an approximation algorithm is also developed for solving the problem.

We have implemented all the proposed algorithms and experimented on computer-generated phantoms and clinical data. Comparing with results supervised by experts, the auto-contouring algorithms yield highly accurate results for all tested datasets. The field decomposition and field splitting methods produce treatment plans of much better quality while comparing with the state-of-the-art commercial treatment planning system.