Beamlet Based Intensity-Modulated Radiotherapy Plan Optimization With Particle Swarm Algorithm

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Abstract

The Intensity-Modulated Radiotherapy (IMRT) plan requires an optimization of the weights (fluences) of electron beams. The goal of the process is to maximize the value of dose delivered to the tumor and minimize it at the other regions. The problem is usually given as a set of values specifying minimum dose to be delivered in the PTV (Plan Target Volume) and small maximum dose in a set of OARs (Organs at Risk). The two goals are complemented with constraints like an average dose in a region, maximum dose in a voxel, etc. The problem can be solved as a multicriteria optimization problem with constraints [1]. In the presented paper we propose to apply and analyse efficiency of the Particle Swarm Algorithm.

Most IMRT plans are created by solving the inverse problem in two steps via the beamlet-based approach [2]. In the first step a problem of a pencil-weight optimization is solved, where the beamlet weights constitute the optimization variables. In the second step, the weight profiles are adapted into the plan which can be delivered by the machine multi-leaf collimators.

In our research we have developed a system which is capable of calculating an incident matrix specifying doses delivered to all voxels of planning grid from each pencil-beam (beamlet) of IMRT. The matrix is then used to efficiently evaluate the objective functions and constraints. As a result we have obtained a Pareto front from which a solution can be chosen. The major problem of beamlet-based optimization is a huge number of design variables (which is equal to the number of the fluences of beamlets from fluence maps) resulting in a very rough distribution of doses. To overcome this problem we have represented the beamlet weights on the fluence maps with bell shaped functions, thus reducing the number of design variables by an order of 2. The reduced optimization problem was solved using the Particle Swarm Algorithm which was successfully used by others for gantry angle optimization [3].

References

1. T.S. Hong and D.L. Craft and F. Carlson and T.R. Bortfeld. Multicriteria optimization in intensity-modulated radiation therapy treatment planning for locally advanced cancer of the pancreatic head. Int. J. Radiation Oncology Biol. Phys., 72(4), (2008), 1208–1214. .
2. F. Carlsson and A. Forsgren . Iterative regularization in intensity-modulated radiation therapy optimization. Med Phys., 33(1), (2005), 225–234.
3. Yongjie Li and D. Y. and & Jonathan Yao and W. C.. A particle swarm optimization algorithm for beam angle selection in intensity-modulated radiotherapy planning. Phys. Med. Biol., 50, (2005), 3491–3514. .