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SIMULATION INTENSITY MODULATE RADIATION THERAPY BY USING PENELOPE

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Abstract

In this paper we present a simulation of intensity modulate radiation therapy (IMRT) with PENELOPE. The simulation of IMRT involves two problems. The first one is the modulation with tomotherapy and the second is the modulation with the movement of the multileaf colimator. Obtained results are the distributions of absorbed dose on the target volume and the organs at risk (OARs). The results show that IMRT could give a desired distribution of dose, which is enough for the target to kill the cancer cells and prevent the over dose of OARs. This paper also shows how to use PENELOPE for studies of the distribution of absorbed dose in radiotherapy.

1. Introduction

Radiation therapy technique is one of the first choices in the treatment of cancer. With the development of imaging diagnostic techniques, modern radiotherapy has achieved a tremendous growth in killing cancer cells with high precision and safety for patients. Technical intensity modulated radiation therapy IMRT is a testament for this. The IMRT represents the radiotherapeutic modality where the intensity of the radiation delivered, could be modulated

Key words: radiotherapy, simulation with PENELOPE, IMRT.

during the treatment in order to focus on the tumor tissue and spare the adjacent anatomical structures/tissue(s). Therefore, the increased dose of radiation is delivered to the tumor [1]. The IMRT planning starts with target and normal tissue definition, continues with dose prescription, and inverse planning. Using computer optimization, multiple small fields are designed to give a complex and conformal radiation dose distribution. Therefore, the survey method of IMRT, especially the distribution of absorbed dose in IMRT, makes a big attraction both in research and applications. Penelope-language computer program is using FORTRAN 77 implementation of Monte Carlo simulation of electron transport, photon and positron in any material with a wide energy range, from a few hundred eV to about 1 GeV [2]. This report presents the calculated dose distribution for the complex radiation problem as IMRT with Penelope.

2. Implementation of simulation

The simulation in this report includes two problems: 1. The simulation of the intensity modulated radiation through the change of the position of the leaves in the collimation system multiple sheets (MLC) and 2. The simulation through intensity modulation allowing irradiation cut class (tomotheraphy).

For the first simulation, simulation space is a mini MLC tungsten size 10 mm x 30 mm x 60 mm including 20 pairs of leaves moved independently, and soft tissue phantom size 10 mm x 8 mm x 2 mm. The projection perpendicular to the field is divided into 80 voxel. This size is taken from real size of miniMLC system used in radiation therapy to the head and the brain [3].

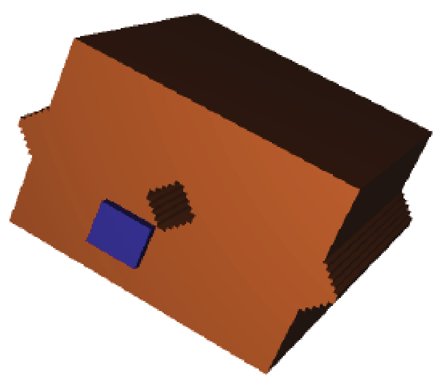

Figure 1: *Space simulation problem 1*

To allow variability, miniMLC system is divided into five segments with 5 of the MLC system format. Selected photon beam simulation characteristics like beam photon in the output of Co-60 radiation therapy device is:

- Energy 1.25 MeV.

- The parallel beam projection covers all situations of MLC (such projection is 10 mm x 10 mm for us miniMLC).

Parallel beam spread options in a plane 10 mm x 10 mm is an important issue to ensure the accuracy of the simulations. In this case, we simulated source in parallel with a single source system of spread radiation in the plane 10 mm x 10 mm to the mini MLC 10 cm.

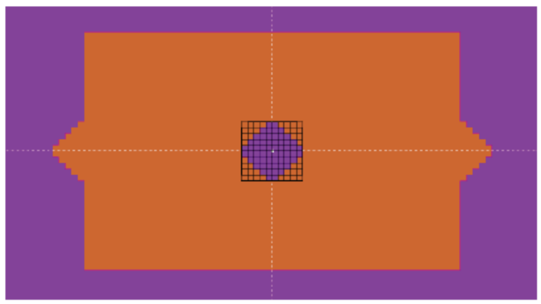

Figure 2: *Mesh distribution of the radiation the source position problem 1*

For the second simulation, simulation space is still the MLC system but the position of the MLC system can be shifted around the target to create the optimal dose. This simulation conducted to calculate with 16 basic projection fields around C-shaped tumor (a common type of tumor in the treatment of head, neck and need to apply IMRT)

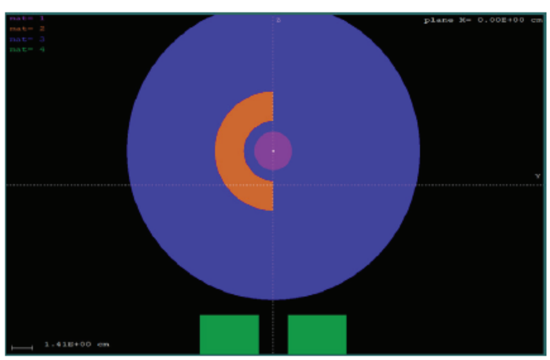

Figure 3: *Space simulation problem 2*

3. Results and discussion

For the first problem, from the DAT file for results, the absorption energy in the block has been defined. It has the energy above 80 voxel phantom of 20 pairs of MLC - the values are of interest. These values are converted to matrices to process and display the results of the five segments shown in the table 1.

Table 1:

total=1.0e+004*[	0.0104	0.0277	0.0754	0.2823	0.4803	0.4835	0.2824	0.0761	0.0273	0.0095;...
	0.0285	0.0841	0.3026	0.5587	0.7762	0.7804	0.5547	0.2998	0.0818	0.2073;...
	0.0717	0.2984	0.5562	0.8208	1.0469	1.0405	0.8165	0.5536	0.2965	0.0692;...
	0.2510	0.5142	0.7885	1.0548	1.2698	1.2631	1.0424	0.7714	0.5028	0.2504;...
	0.2540	0.5193	0.7879	1.0500	1.2754	1.2789	1.0410	0.7762	0.5062	0.2521;...
	0.0682	0.2981	0.5574	0.8172	1.0402	1.0564	0.8180	0.5582	0.2956	0.0703;...
	0.0275	0.0839	0.3050	0.5537	0.7733	0.7791	0.5541	0.3017	0.0803	0.0267;...
	0.0094	0.0276	0.0755	0.2835	0.4734	0.4804	0.2803	0.0745	0.0266	0.0091]

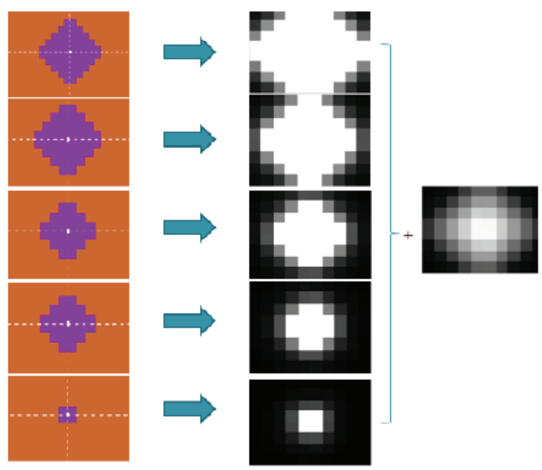

Figure 4: *Results of the variable intensity of the problem 1*

This simulation allows intensity modulated radiation therapy, the IMRT can allow changing the material absorbs energy in a range of values depending on the planning permission for the MLC system in order to create a necessary absorbed dose to the desired location on the tumor. For all simulation 2, the basic projection from 16 fields around the target nine fields were selected basic projection (Figure 5) according to the following criteria:

- Creating high and uniform dose to the tumor;

- Avoiding direct reference to the organization in the danger zone (In fact, the application will use the optimal algorithm in terms of projection and showtimes)

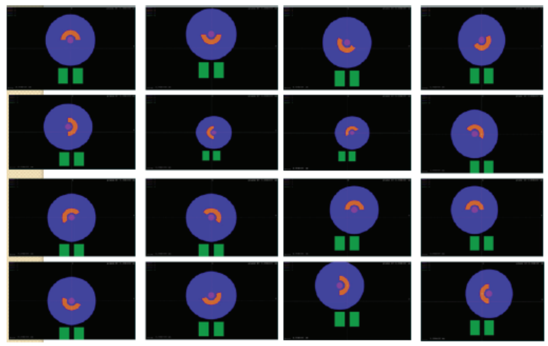

Figure 5: *16 basic projection in the field of problem 2*

The results of energy absorption on OAR, tumor and tissue surrounding water obtained after running the simulation as shown in table 2.

Table 2:

Columns 1 to 8

27.4091	0	0	0	0	0	0	0
12.3345	36.7474	61.1967	18.3117	17.2883	61.2500	38.3638	13.5294
52.8214	60.1534	62.9282	532892	58.2580	63.1154	60.3375	56.0649
19.0397	50.0449	24.0394	30.8067	30.9982	25.9257	49.6482	19.5913
3.6587	37.0864	36.8217	13.9246	15.4727	38.7788	36.7848	3.3767
21.5500	1.5227	7.1124	13.2901	13.0370	7.6165	1.3995	21.3997
17.8837	10.1479	12.2421	11.5957	12.0728	12.2069	11.0873	16.0106
16.6094	15.8024	15.7252	11.5264	12.1778	15.2238	17.3728	16.6179
18.1472	21.4723	20.6673	14.6431	15.0532	18.6190	21.8247	18.8880

Columns 9 to 16

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0.0507	7.1056	5.4689	8.4464	8.8565	5.2558	7.0126	0.0126
0.0627	8.2192	11.8178	4.8070	4.9261	11.3211	8.8455	0.0177
0.1460	10.1814	16.0959	3.6304	3.6177	14.8640	10.0986	0.1341
1.3363	11.3958	19.1445	4.3584	4.4583	19.0690	11.7972	1.1827

Map of the dose distribution blocks after treatment results and display in MATLAB (Figure 6):

Based on the obtained dose map, it was found that: the projection for 9 field choices transfers on tumor phantom at a dose of about 60Gy in the middle of the 1st layer and 2nd layer of tumor dose. In layers 3 and 4, the dose was quite low (especially in layer 4, with the highest dose of about 40Gy). Meanwhile

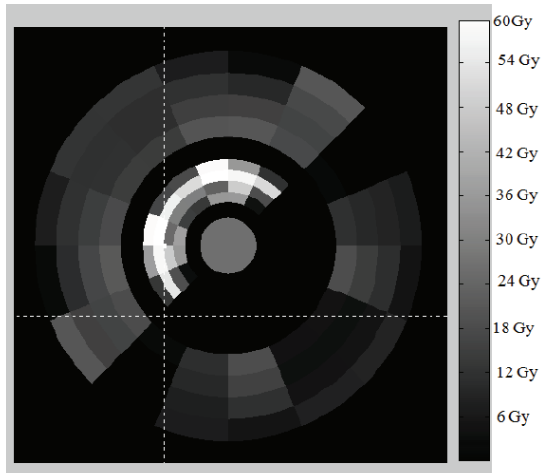

Figure 6: *Map of the dose distribution on the block*

absorbed dose to the OAR is about 27Gy (the dose that allows for OAR in this case is 30Gy). This is a very good result because it allows the transfer of risk. The purpose is to move a relatively uniform dose to the tumor, to reach a desired value while the dose to the OAR below a threshold. Simulation 2 performed according projection and space of phantom 1 in the actual radiation survey equipment IMRT (Figure 7) [4]. Comparing the simulation results of two calculations through simulation by Penelope and the survey results of the raster in IMRT projection of 9 fields, we have similarities as follows:

- The maximum absorbed dose of the OAR in the survey: 30.3Gy.

- The absorbed dose of the OAR in all tissues interview 2: 27.4Gy.

- The absorbed dose of the tumor in the survey from 59.3Gy to 73.1Gy.

- The absorbed dose of the tumor in all simulation 2 of about 60Gy in 2nd layer tumors.

The purpose of the two simulations are the uses of Penelope tools to simulate IMRT method on a fundamental phantom model. The results showed that:

- IMRT method by changing the position of the leaves on the MLC system in the first problem allows the shape and intensity modulated projection irradiated onto the surface according to the shape and density of the tumor. It has been demonstrated that we can transfer, at a position angle, the desired dose to the tumor varied in shape, size.

- IMRT for tumor projection in a variety of different angles in space as in problem 2. By combining multiple angle projection (many projection) of raster therapy with each projection angle corresponding to the different variables, which can create an optimal dose distribution to the tumor. In tomog-

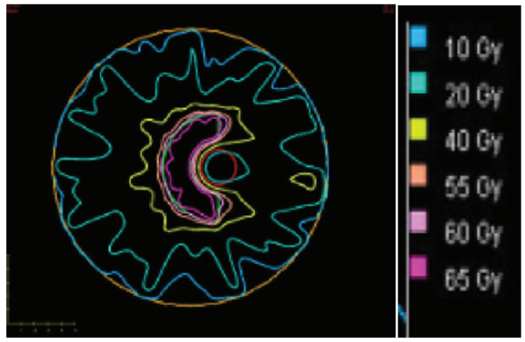

Figure 7: *Photo irradiation IMRT 9 fields with the eclipse planning software [3]*

raphy method, dose distribution manually selected based on a number of key projection to the criteria chosen to create high and uniform dose to the tumor while limiting field direct projection to OAR to avoid creating high doses. In fact the computer software will be done select the optimal dose distribution to automatically thanks to the optimal dose distribution algorithm complexity (such term DAO algorithms).

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