Cancer treatment using optimization methods

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Optimization Class Project. MIPT

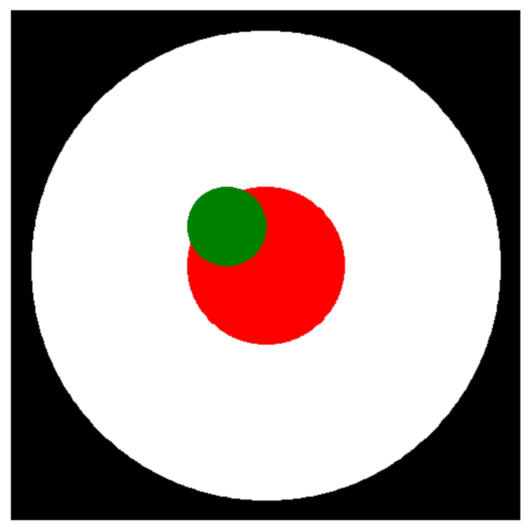
Introduction

This year in the United States more than 1,200,000 people will be diagnosed with cancer. More than half of these cancer patients will be treated with radiation at some point during the course of their disease. Radiotherapy refers to the use of radiation as a means for treating disease.

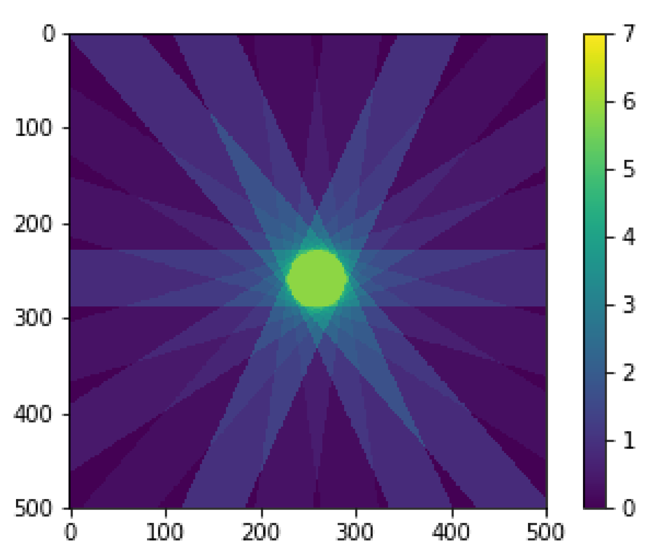
Based on the article, using the Linear Programming Approaches we will try to optimize the irradiation of the tumor and reduce it for healthy tissues.

Model

- We represent a section of the body as a white circle, the tumour as a region of red colour and a sensitive area that cannot be irradiated, for example the spinal cord as a region of green colour.



- Radiation occurs with the help of N lamps of a given width. At each pixel, the intensity of irradiation is summed up from several beams. By varying the intensity of each, it is possible to obtain a different irradiation of each area of the body.



Linear Programming approaches for this task

$$\min_{w} \sum_{(k,l)\in N} D_{kl} + \theta \sum_{(k,l)\in R} D_{kl}$$

$$Dij = \sum_{p=1}^{n} w_p D_{ij}^{p} \quad \forall (i,j)$$

$$\gamma_l \leq D_{kl} \leq \gamma_u \quad \forall (k,l) \in T$$

$$w_m \leq \frac{\alpha}{n} \sum_{p=1}^{n} w_p \quad m = 1, 2, ..., n$$

$$w_p \geq 0$$

- D_{ij}^{p} - dose from beamlet p in pixel with i, j coordinates
- w_p - beam weight
- T is the subset of the pixels located in the tumor
- n is the number of beamlets
- γ_l and γ_u indicate the lower and upper bounds on the dose to the target
- R is the subset of pixels in the region at risk, and N is the subset of normal tissue pixels
- θ is a ratio of the region at risk weight and the normal tissue weight. (weighting factor)

Parameters

The following parameters were selected for this task:

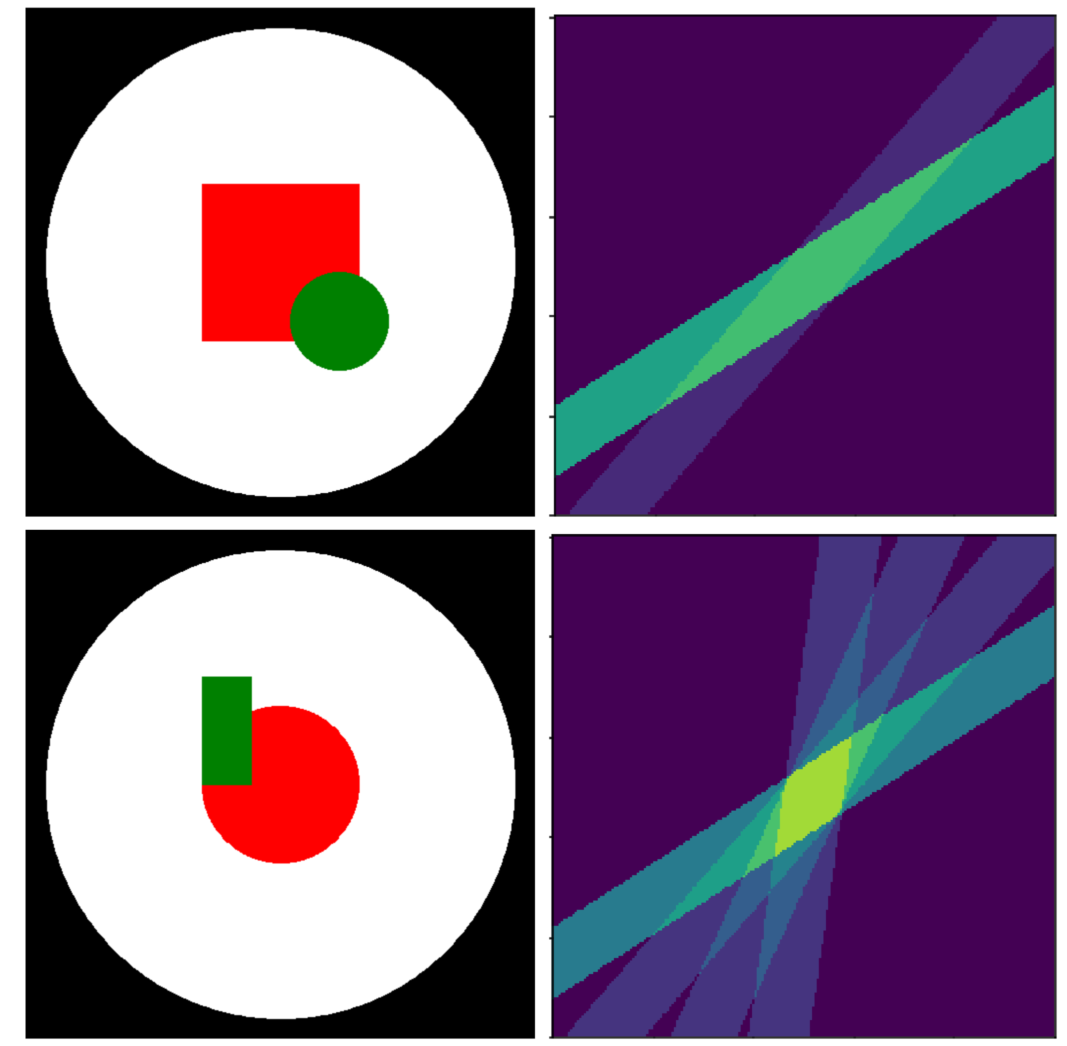
- Image size 500 * 500 pixels
- $m = 60$ - beam width
- $N = 11$ - number of beams
- $\theta = 0.8$ - the number that the expert sets
- $\alpha = 2.4$ - is a chosen number for the optimal solution of the problem

Method

The problem is solved with the help of library scipy.optimize, a function linprog using the simplex method

Results

For these parameters, the following results were obtained.



Conclusion

The two primary advantages of the use of a linear programming approach to treatment planning optimization are its speed and the ease of formulation. A disadvantage of the linear programming formulations is a lack of flexibility. One can only devise a relatively limited number of objective functions and constraints that fall within the linear realm. With any particular linear programming formulation, it is unlikely that a physician could always achieve an acceptable result.

Educational value of the project

- training in constructing a LP problem
- fixing skills of working with images, as with arrays of data
- training in solving a LP problem by python
- ability to present my work in a poster or presentation

Acknowledgements

- This material is based upon work supported by the article "Optimizing the Delivery of Radiation Therapy to Cancer Patients" Mackie, T. Rockwell; Olivera, Gustavo H.; Ferris, Michael C.; Shepard, David M., 1998, SIAM REVIEW Vol. 41, No. 4, pp. 721744
- Implementation of this method
  $https://drive.google.com/file/d/1YNlCwQ37BUf_KSEBRrlnthy N4hVWXn0Y/view?usp = sharing$