Exercise class – Ex8

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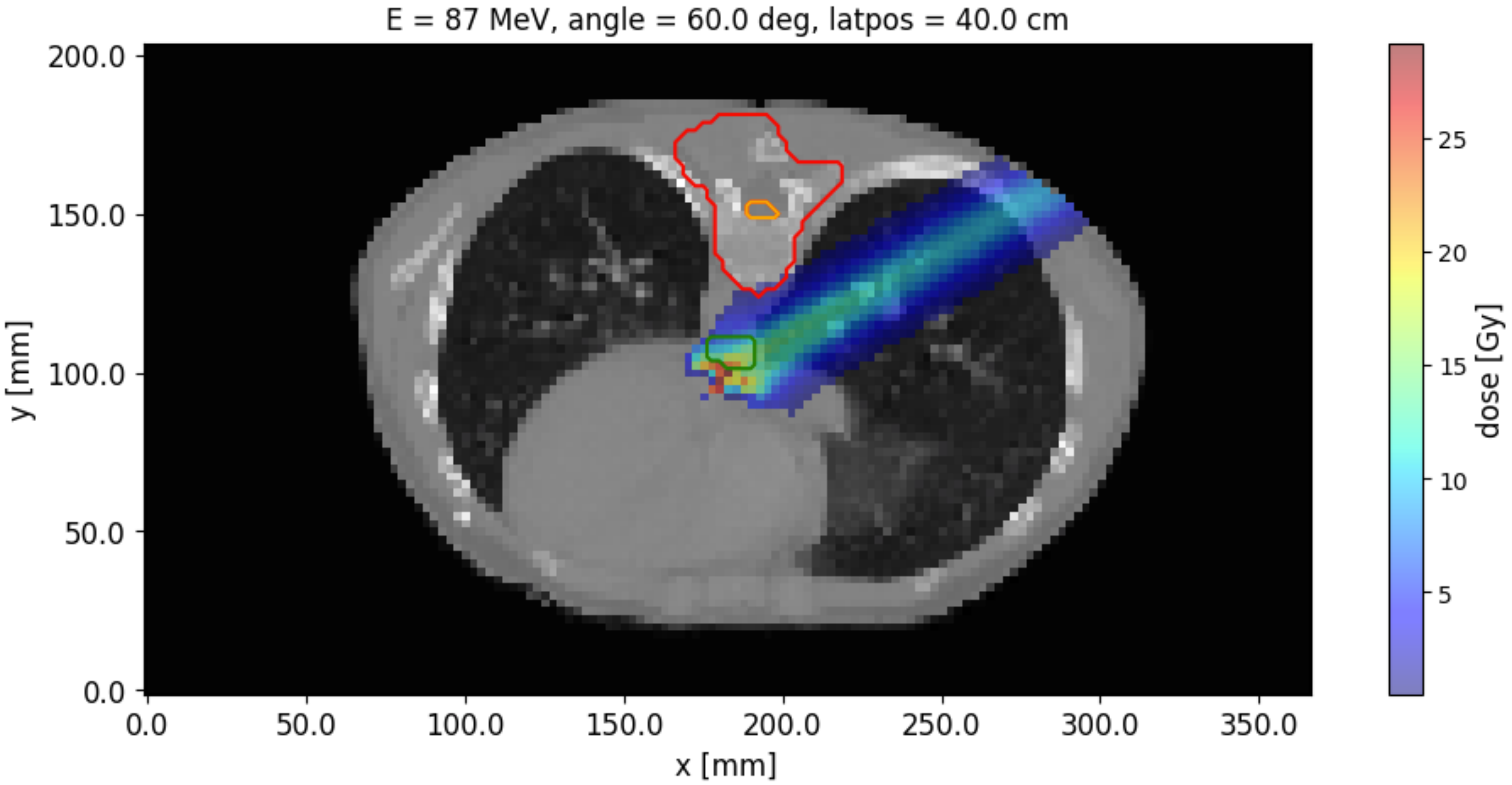
Exercise 6

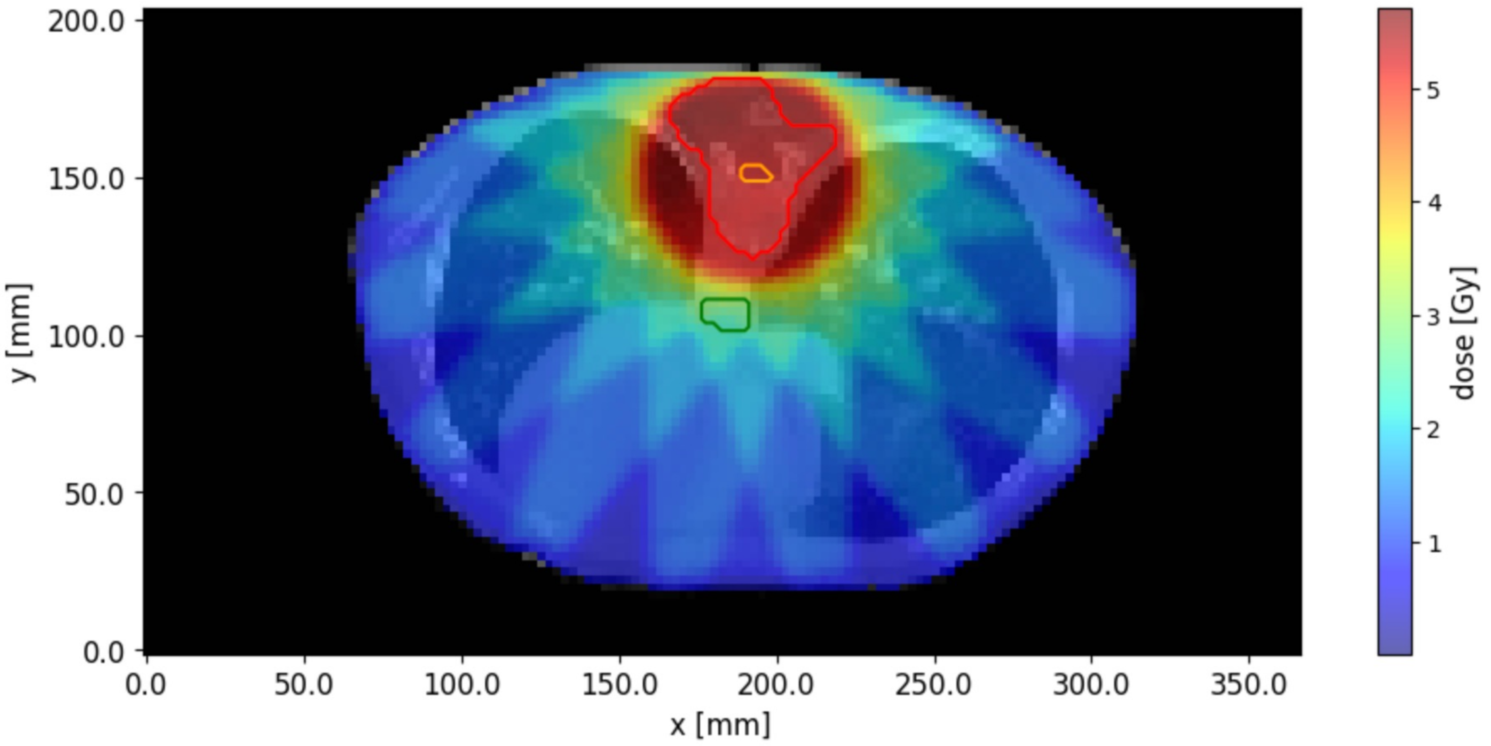
Mostly well solved!



Student solution for ex. 6

Exercise 7

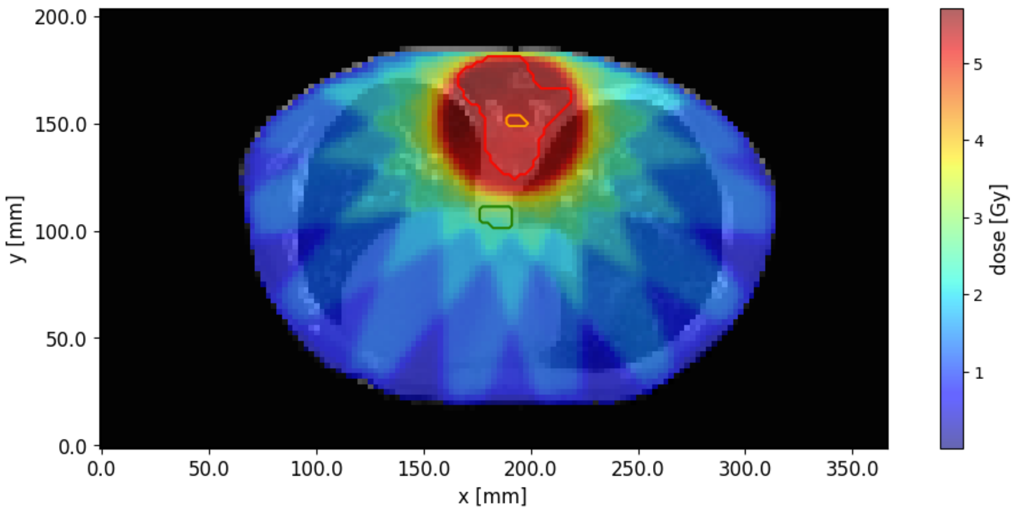
Compute the photon dose-influence matrix!



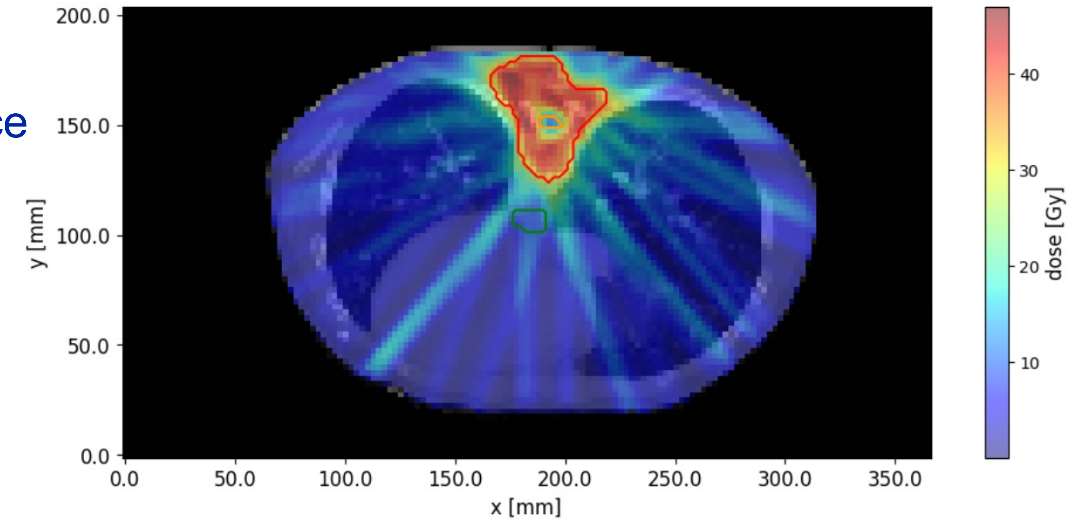
Any questions regarding ex.7?

Exercise 8

Implement IMRT fluence map optimization algorithm!



Optimize fluence of beamlets F_j



Exercise 8

How do we do that?

Minimize **quadratic objective function** with gradient descent:

$$f(d) = \sum_i w_i^o \left(d_i - D_i^{max}\right)_+^2 + \sum_i w_i^u \left(D_i^{min} - d_i\right)_+^2$$

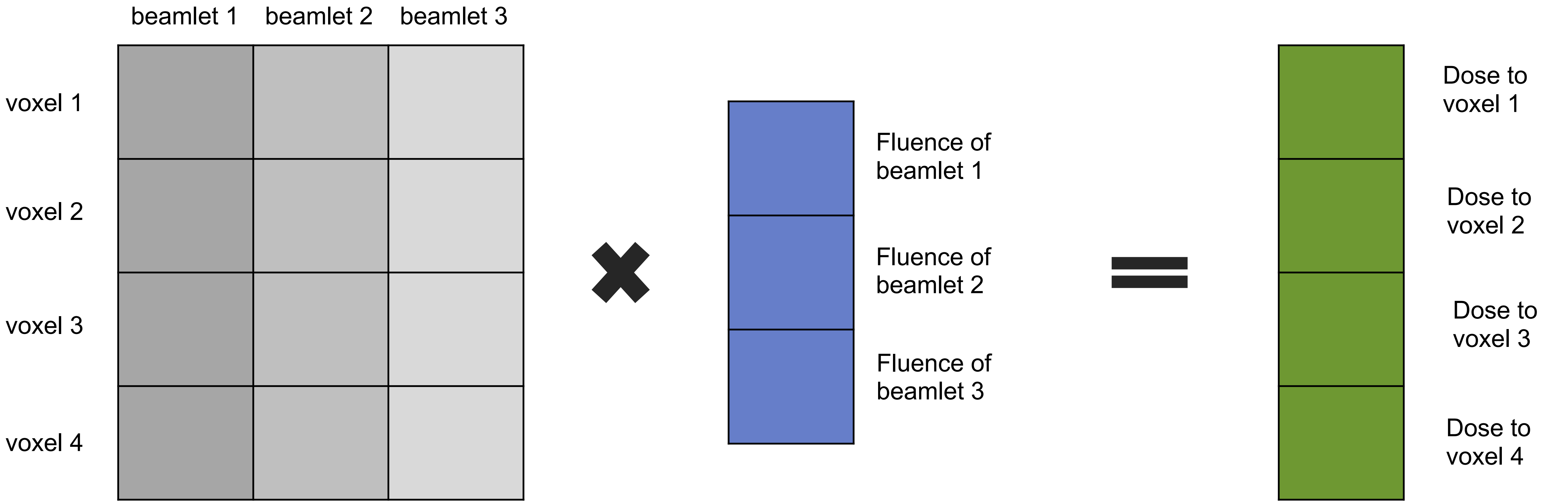
D_i^{max} is the maximum dose to voxel i,
D_i^{min} is the minimum dose to voxel i,
w_i^o is the overdose penalty factor for voxel i,
w_i^u is the underdose penalty factor for voxel i

Exercise 8

Note: Dose *d* is a 1-d vector!

$$d_i = \sum_j D_{ij} * F_j$$

$$f(d) = \sum_i w_i^o \left(d_i - D_i^{max}\right)_+^2 + \sum_i w_i^u \left(D_i^{min} - d_i\right)_+^2$$



D_{ij} with 3 beamlets

Fluence vector F

Total dose to every voxel d

Exercise 8

Step 1

Define dictionary **TPopt** holding all parameters for each structure

```
TPopt['vois'][1] = {
     'name': 'normal tissue',
     'nVoxels': np.sum(voi == 1),
     'maxdose': 50,
     'overdosepenalty': 1,
     'mindose': 0,
     'underdosepenalty': 0,
}
```

and summarize them to vectors the same size the dose vector

```
TPopt['maxdose']
TPopt['mindose']
TPopt['overdosepenalty']
TPopt['underdosepenalty']
```

Reshape to 1d arrays!

Exercise 7

Step 2

Write a function `calculate_quadratic_objective(bixelweights)` that computes the **value of the objective function**, give a vector of beamlet intensities.

$$f(d) = \sum_i w_i^o \left(d_i - D_i^{max}\right)_+^2 + \sum_i w_i^u \left(D_i^{min} - d_i\right)_+^2$$

Step 3

Write a function `calculate_quadratic_objective_gradient(bixelweights)` that computes **the gradient of the objective function**, give a vector of beamlet intensities.

Exercise 7

Step 4

Write a function `optimize_gradient_descent(nIterations, stepsize)` which implements **gradient descent** to minimise the quadratic penalty function.

0. Initialize the beamlet intensities $F_j = 0 \; \forall j$
   Choose a step size α.

The algorithm consists of iterating the following steps until convergence:

1. Given the beamlet intensities F^k of the current interation k, calculate the gradient

$$\left. \frac{\partial f}{\partial F_j} \right|_{F^k} \tag{2}$$

   of the objective function with respect to the beam intensities.

2. Update the beamlet intensities according to

$$F_j^{k+1} = F_j^k - \alpha \left. \frac{\partial f}{\partial F_j} \right|_{F^k} \tag{3}$$

Exercise 8 – What we expect!