Automatic Dose Optimization for Radiotherapy

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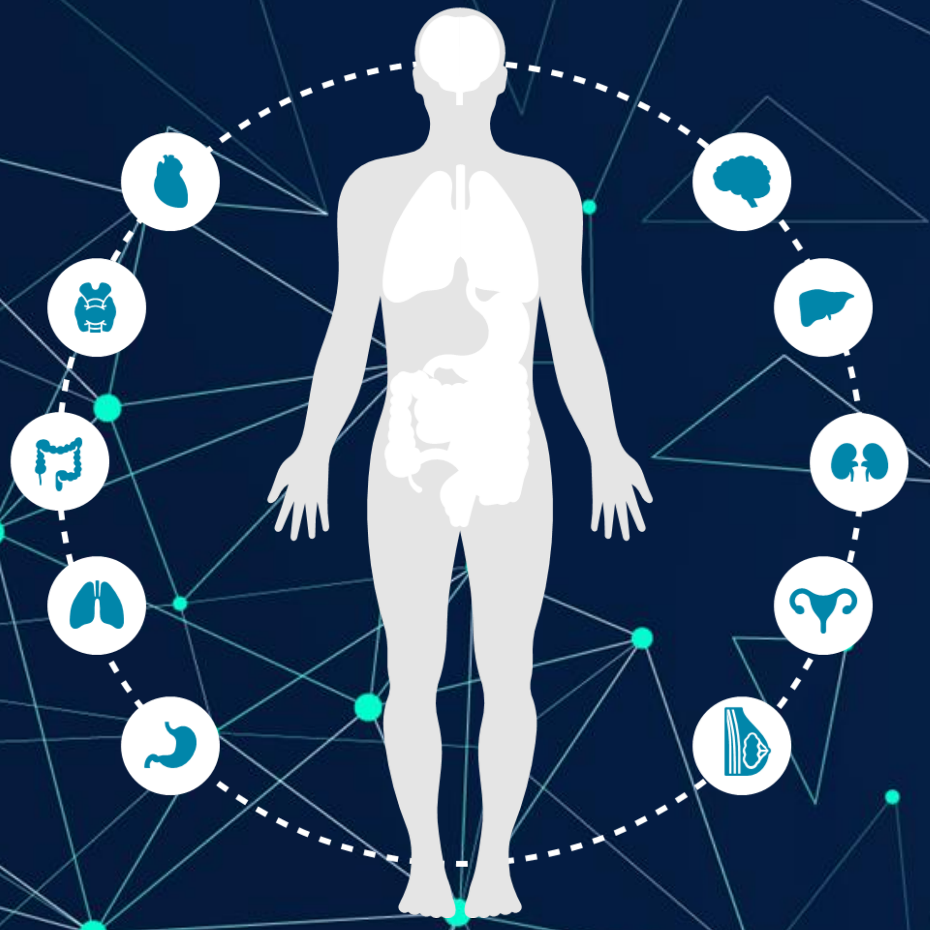


Re-inventing cancer treatment with **Artificial Intelligence**

THERAPANACEA

Reinventing cancer care through AI

TheraPanacea Overview

Company is spin-off of **Artificial Intelligence research** lab

Founded in 2017 and based in Paris & Pittsburgh, **70+ employees** to date

Core expertise in **Advanced Mathematics, Medical Imaging and AI**

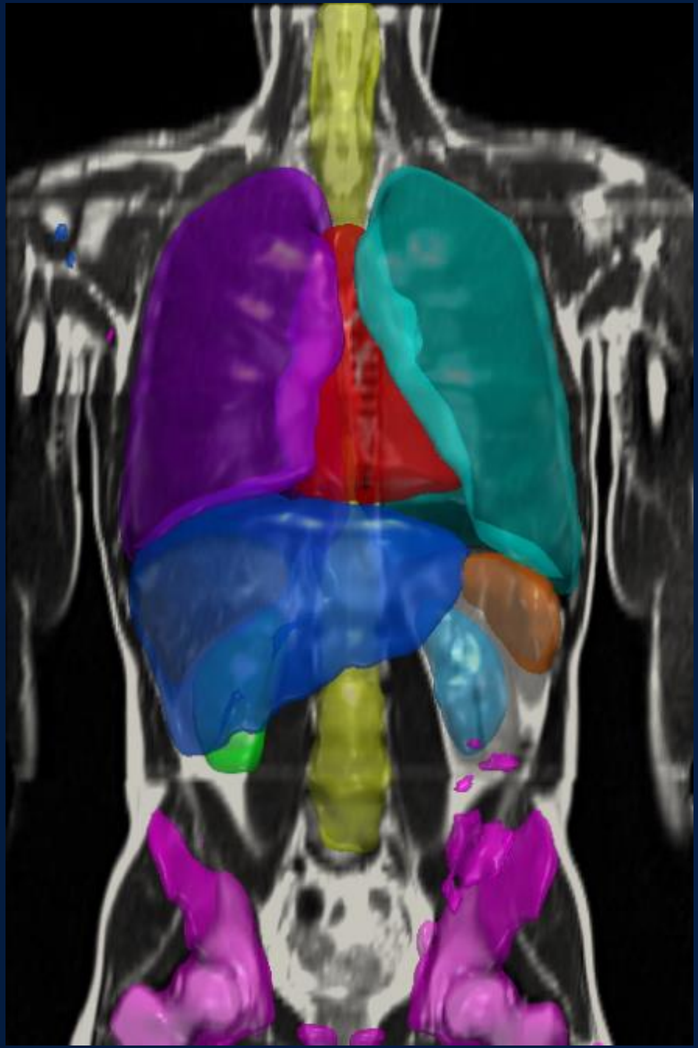
ART-Plan solution for Radiation Oncology 1st market launch in 2019

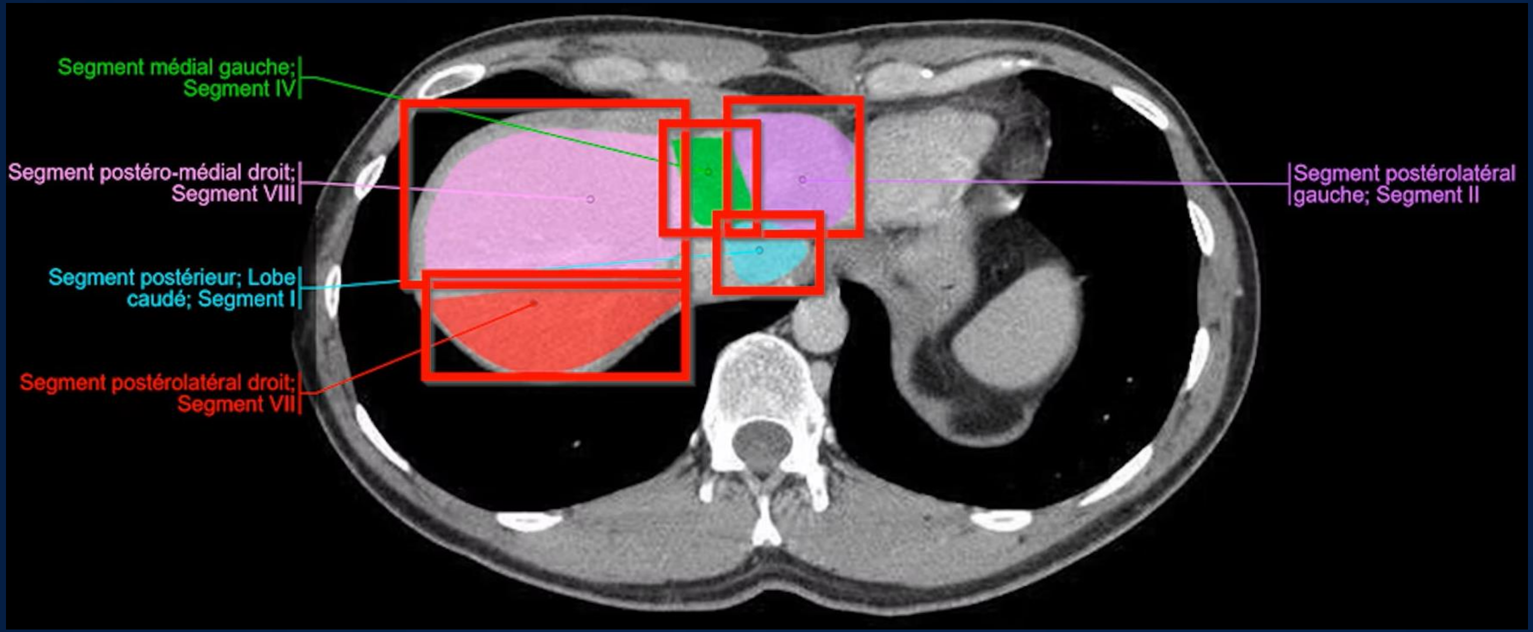
100+ user sites in Europe, Africa, Middle East and the US

European and National Science and Innovation Prizes and Awards obtained since 2017:

H2020 ERC POC, Grands Prix d'Innovation de la Ville de Paris, Concours d'innovation numérique, Concours iLab des jeunes entreprises innovantes, Paris Region AI challenge, Prix de l'innovation en imagerie médicale Société Francaise de Radiologie

Annotation





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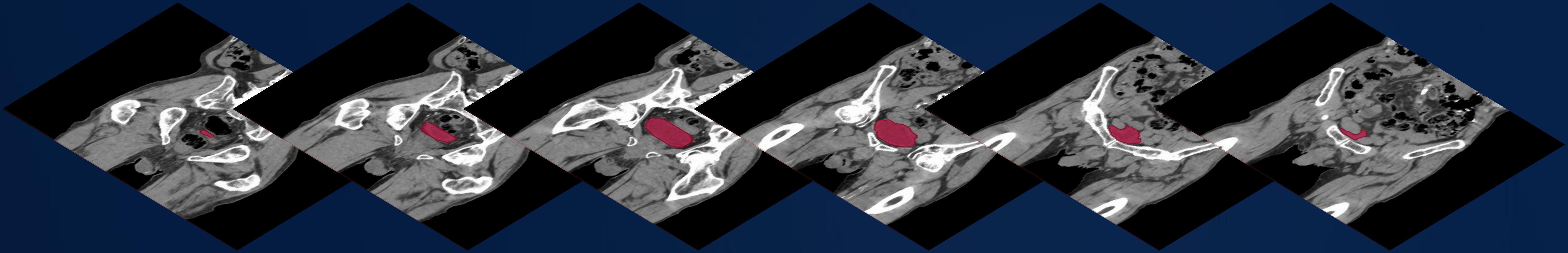
Annotation



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Annotate

AI-powered contouring tool

In clinical use since 2019

150 + structures (OAR and LN) on CT

→ Sub structures of the heart

→ SBRT Thorax

70 + structures on MR

3-4 minutes contouring

Plug and play

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MR Box

Synthetic CT for MR-guided workflow

Automatic delineation on MR

Generate a pseudo-CT from MR images

- Avoid registrations errors
- Accelerate adaptive routines
- Less machine time

Brain T1, Pelvis T2, Pelvis/Abdo Truefisp (ViewRay)

And more under development

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ART-Plan™ AdaptBox

Advantages

Accelerate, automatize and simplify adaptive radiation therapy.

Reduce the burdens of multiple manual Iterations.

Save time and optimize the resources of your department.

Take earlier and easier re-planning decision.

Cancer treatments

Surgery

+: Safe (little damage to healthy tissues)
-: Tumor needs to be localized & accessible

Chemotherapy

-: Heavy medicine on all the body
+: Tumor does **not** need to be localized

Cancer treatments

Surgery

Radiotherapy

Chemotherapy

+: Safe

-: Tumor needs to be loca

+: Relatively safe (most tissues are spared)

-: Tumor needs to be (relatively) localized

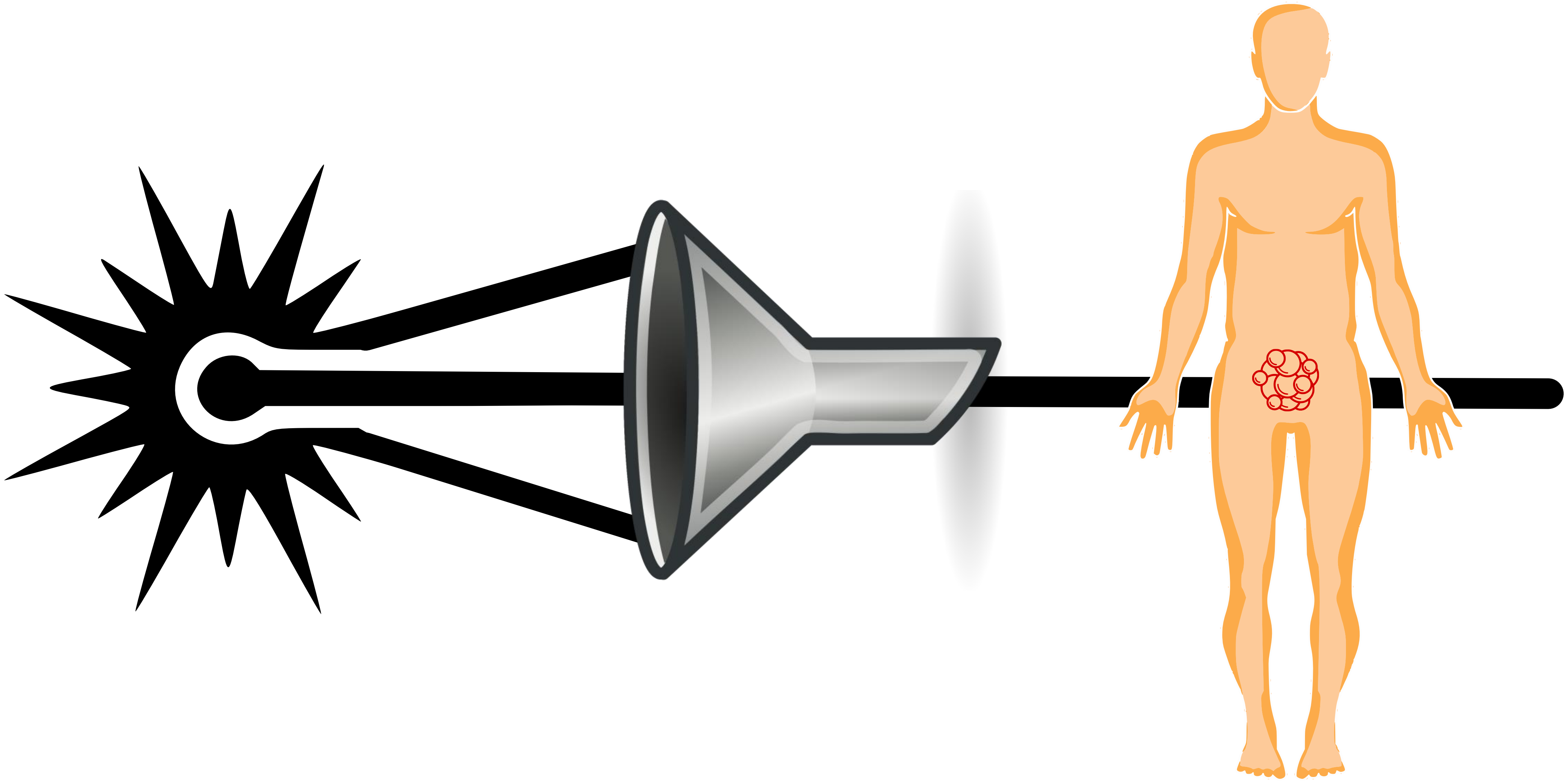
cine on all the body

s **not** need to be localized

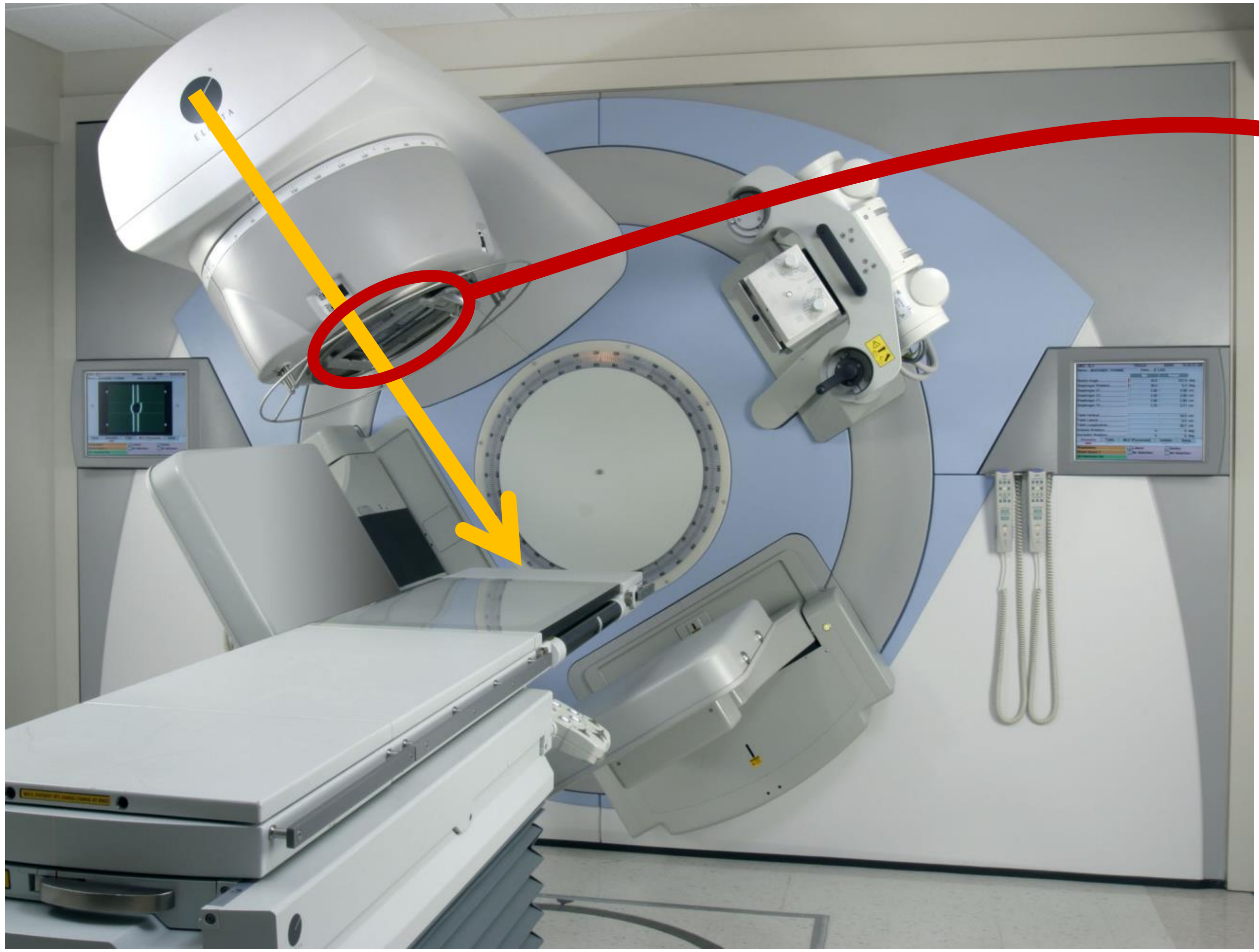
Waves are…

Poison!

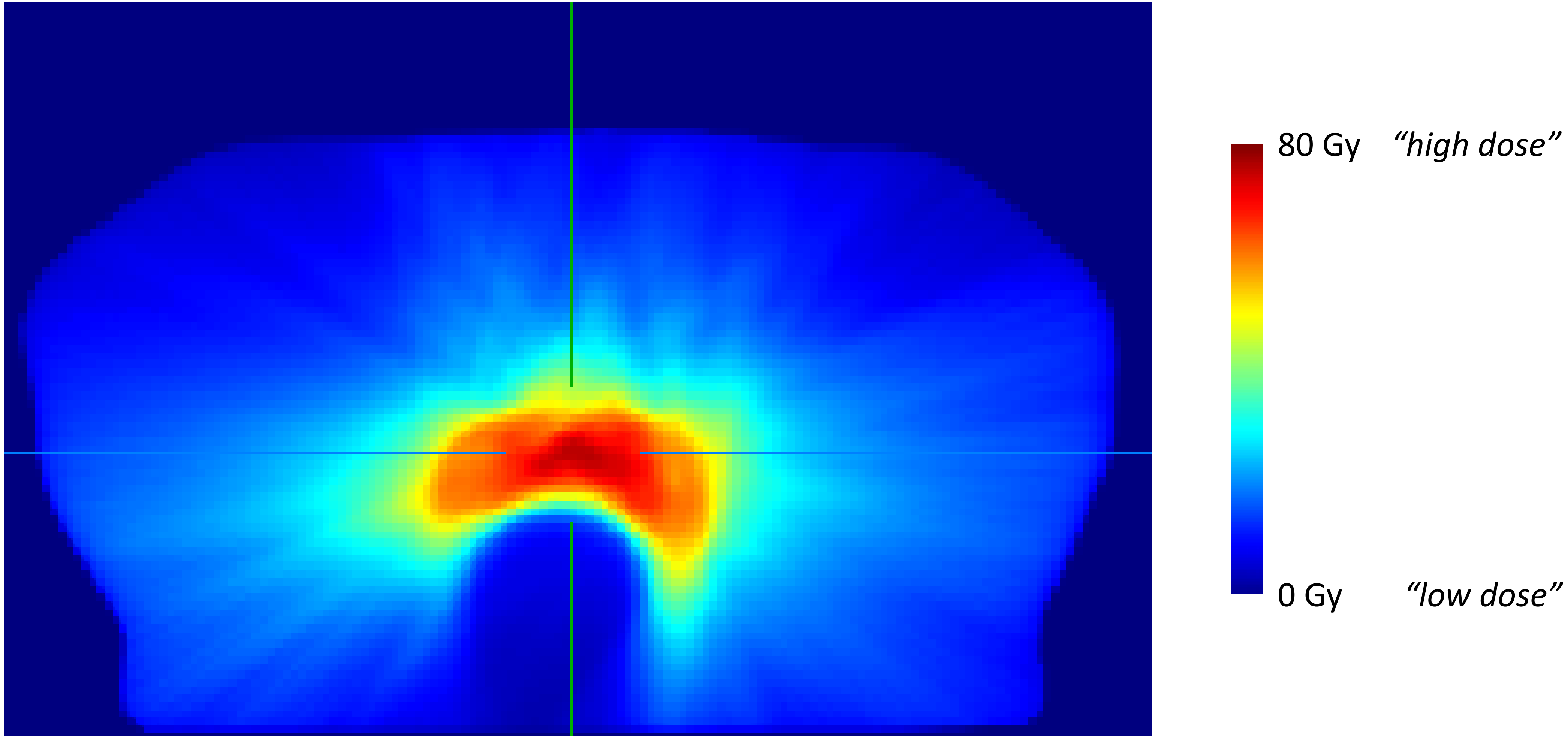
Targeting the tumor



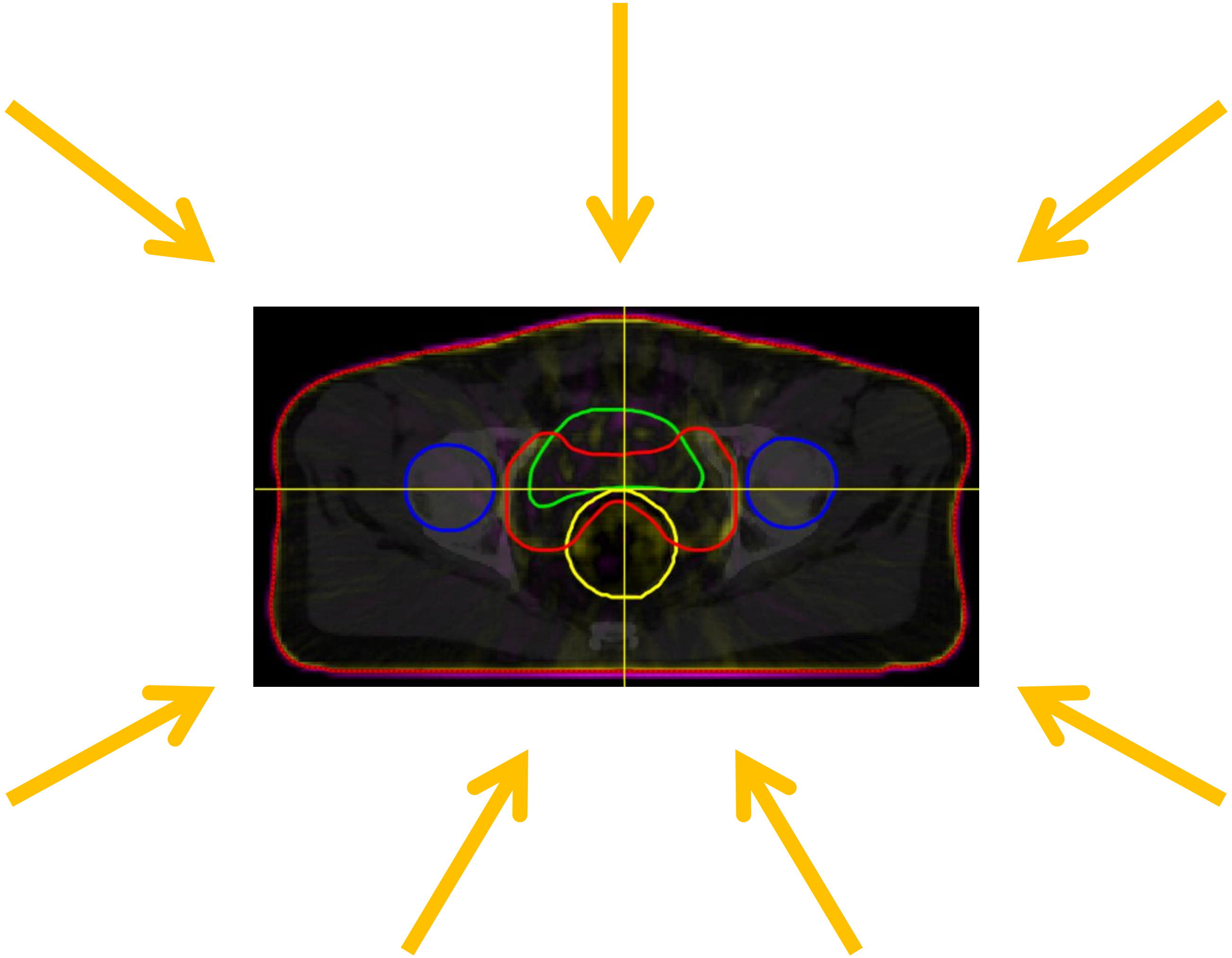
Multi-Leaf Collimator



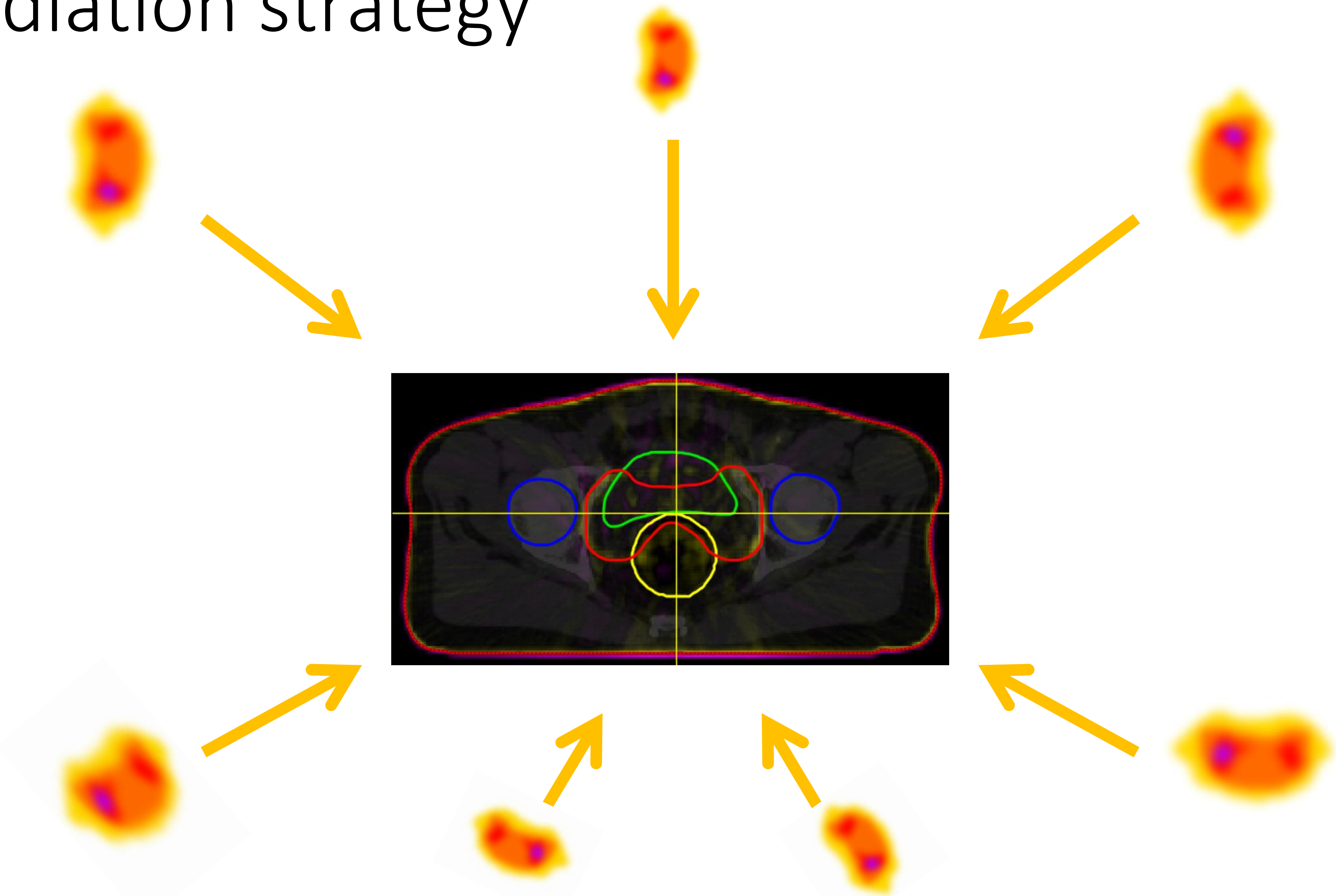
Dose Spread



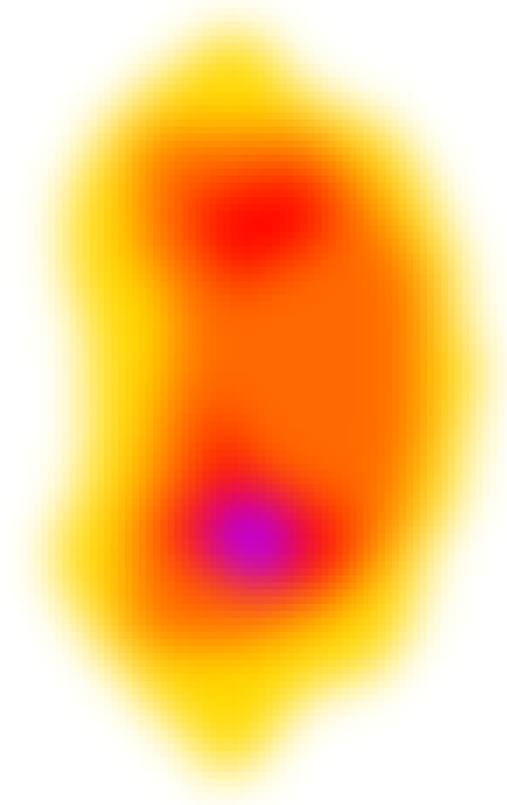
Spreading rays



Irradiation strategy



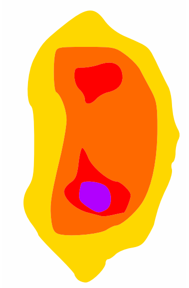
Delivering irradiation



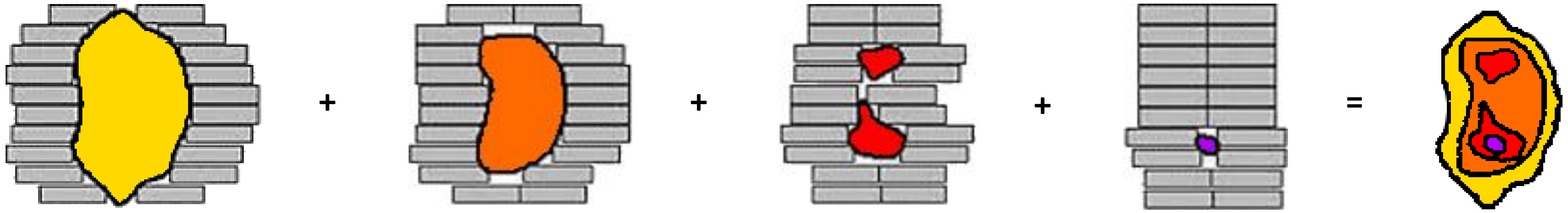
Ideal heatmap

Discretized heatmap

Delivering discretized dose



dose to deliver



Problem statement

% of the volume	Name	Dose
	PTV constraints:	
$\leq 1\%$	of Ext_Tumor receives	$\geq 70\text{Gy}$
$\geq 95\%$	of Tumor receives	$\geq 63\text{Gy}$
	OAR constraints:	
$\leq 1\%$	of Spinal_Cord receives	$\geq 43\text{Gy}$
$\leq 15\%$	of Heart receives	$\geq 30\text{Gy}$
$\leq 20\%$	of Esophagus receives	$\geq 10\text{Gy}$
$\leq 2\%$	of Lt_Lung receives	$\geq 20\text{Gy}$
$\leq 8\%$	of Lt_Lung receives	$\geq 10\text{Gy}$

List of “objectives”

Mathematical formulation

Parameters to optimize

$$x_{i,j}^{(\theta)} \text{ with } 1 \leq i, j \leq N_{leaf\_pairs}$$
$$\theta \in \Theta \text{ (the list of angles chosen for this case)}$$

Parameters constraints

We cannot send negative dose, i.e.:

$$x_{i,j}^{(\theta)} \geq 0$$

however, the angles are completely free.

Dose calculation

The dose on each voxel of the body y_v is approximated by:

$$y = \sum_{\theta \in \Theta} L^{(\theta)} x^{(\theta)}$$

We want to find the best dose distribution y.

Mathematical formulation

Ideal problem

$$\text{minimize} \sum_{s \in \mathcal{O}} \frac{1}{|\mathcal{V}_s|} \sum_{v \in \mathcal{V}_s} y_v^2$$
$$\text{s.t. DVH are respected,} \quad y = Lx \text{ and } x \geq 0$$

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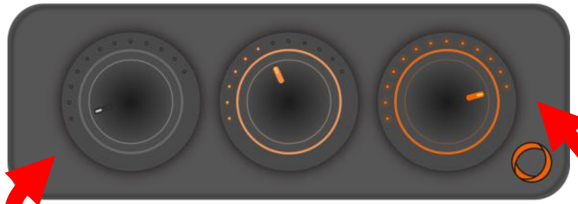


Objective function

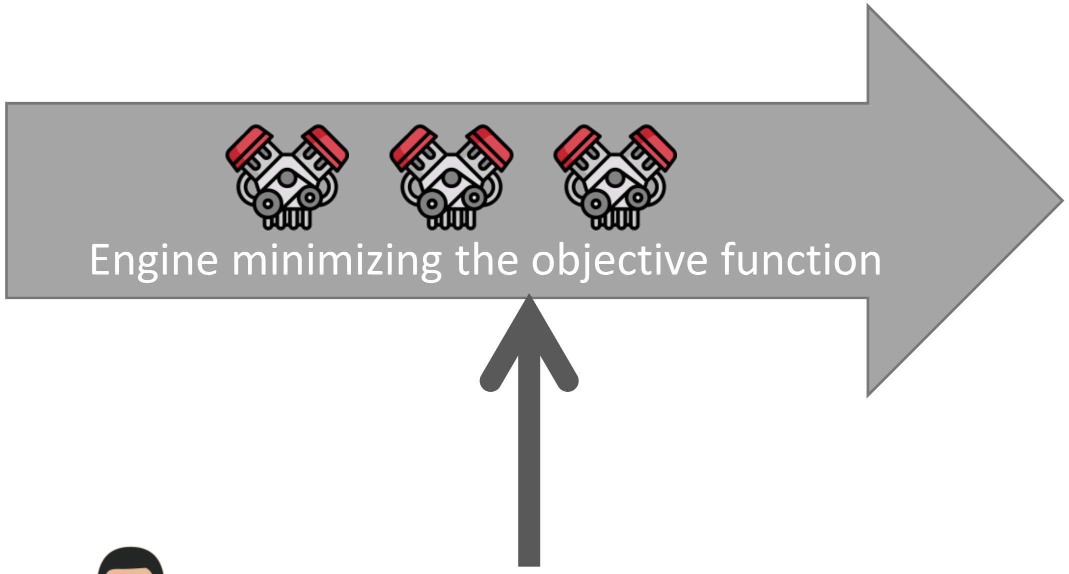
$$f_s(y) = \sum_{v \in \mathcal{V}_s} \frac{1}{|\mathcal{V}_s|} \left(\overline{w_s}(y_v - \overline{t_s})_+^p + \underline{w_s}(-y_v + \underline{t_s})_+^p \right)$$

$$f(y) = \textstyle\sum_{s \in \mathcal{S}} f_s(y)$$

if constraint is not satisfied for structure s, else $f_s(y) = 0$

Current Workflow

Patient data
- CT scan
- OARs & PTVs contours
- doctors' objectives

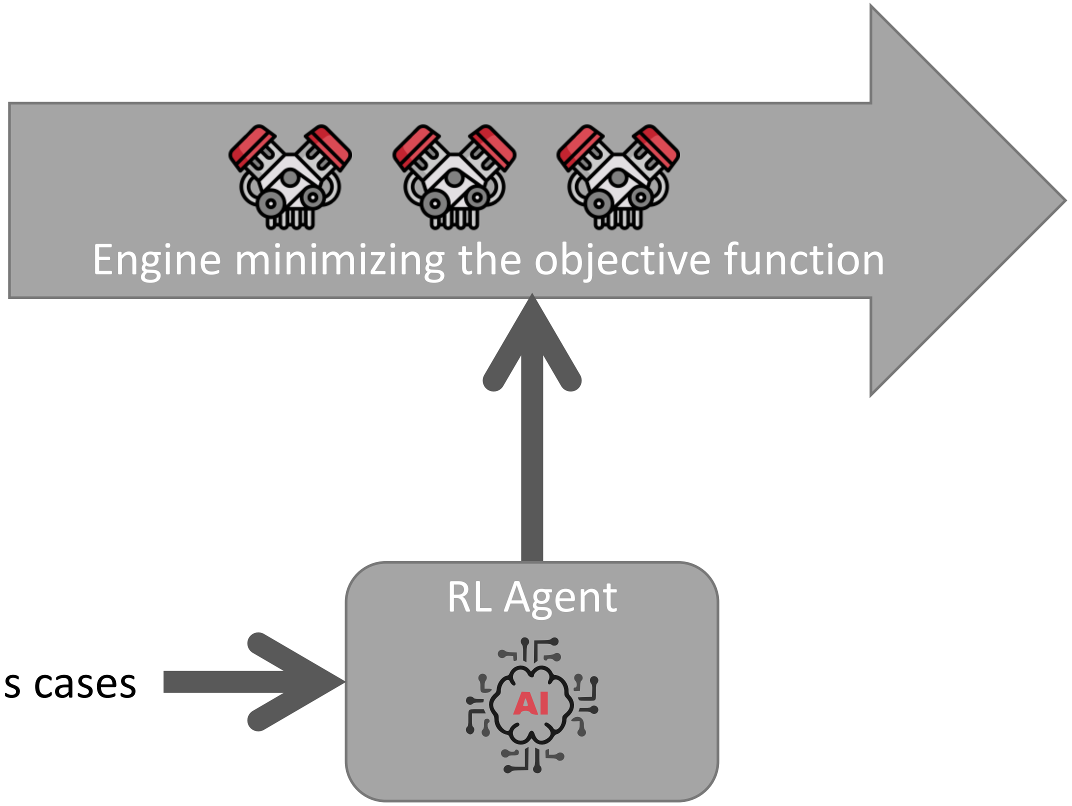


Treatment plan
- Fluences
- Leaf movements
- Dose per organ

Input from dosimetrist
- Weights of each objective

Automatization *(work in progress)*

Patient data
- CT scan
- OARs & PTVs contours
- doctors' objectives



Treatment plan
- Fluences
- Leaf movements
- Dose per organ

Learning based on previous cases

Thank You