Automatic Dose Optimization for Radiotherapy

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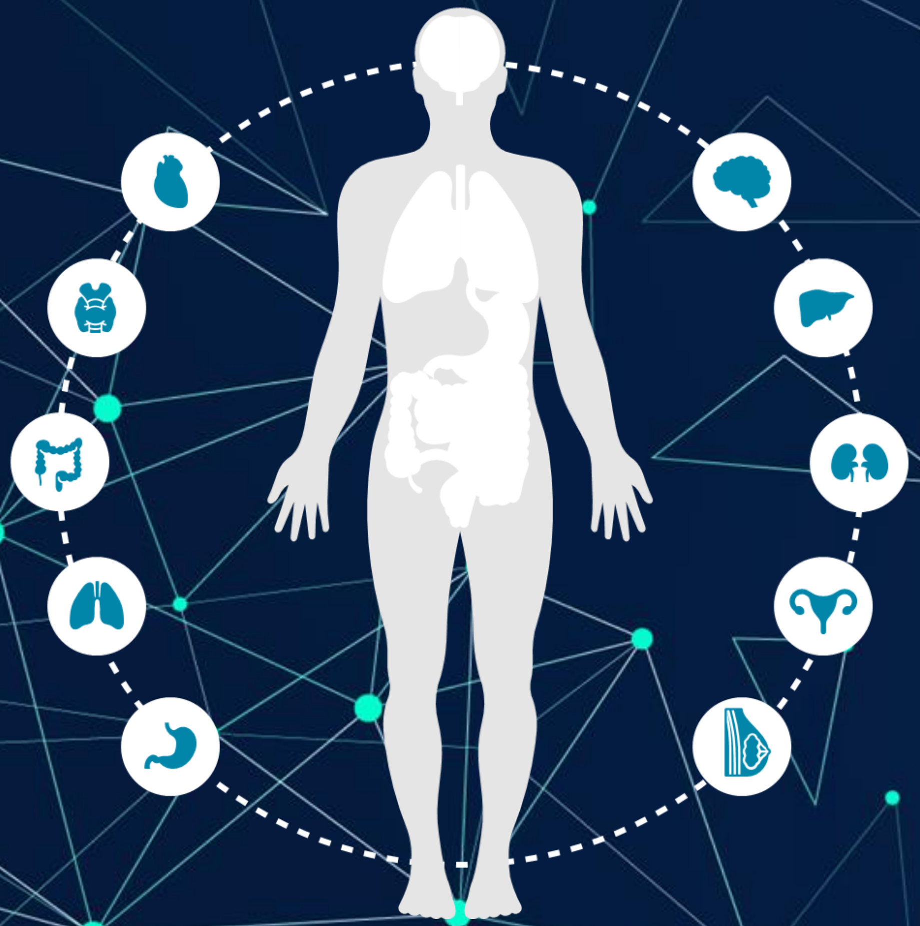
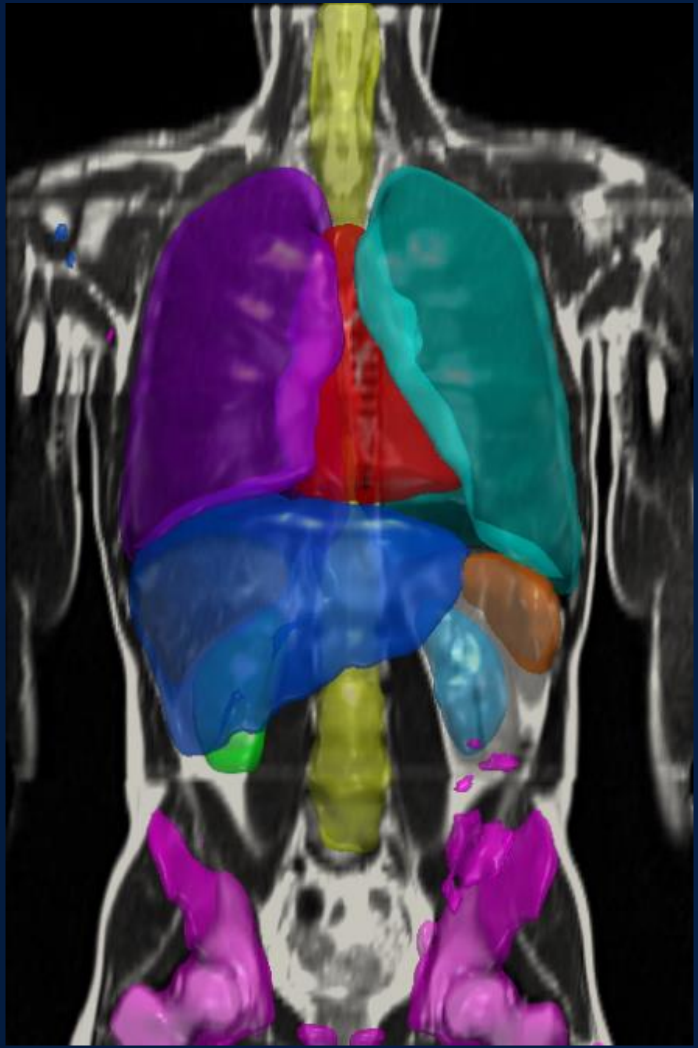


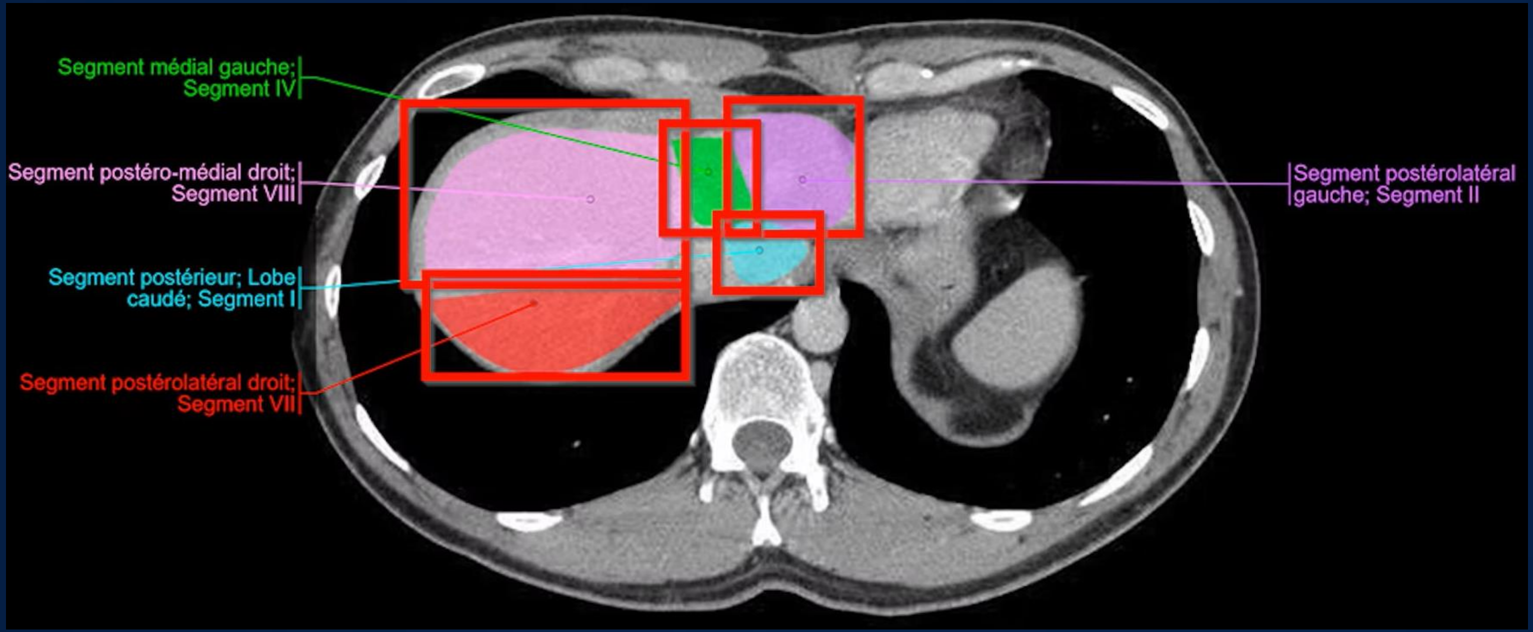
Re-inventing
cancer treatment with
Artificial Intelligence

THERAPANACEA

Reinventing cancer care through AI

Annotation





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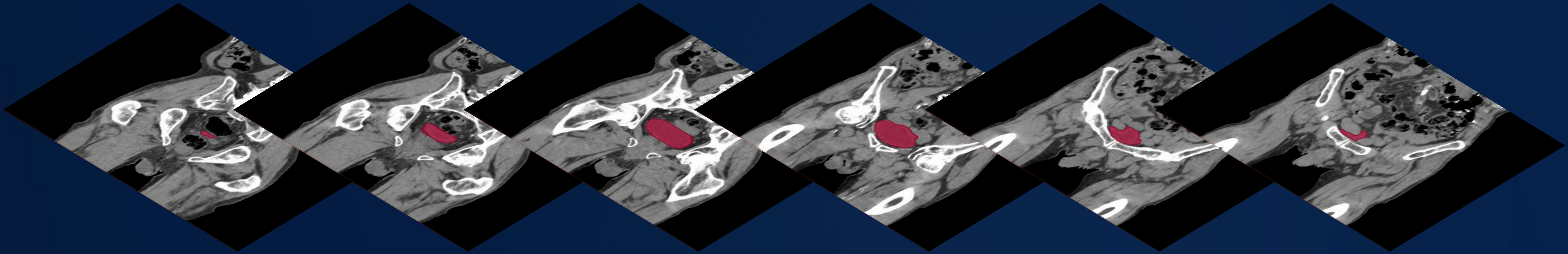

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Annotate

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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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

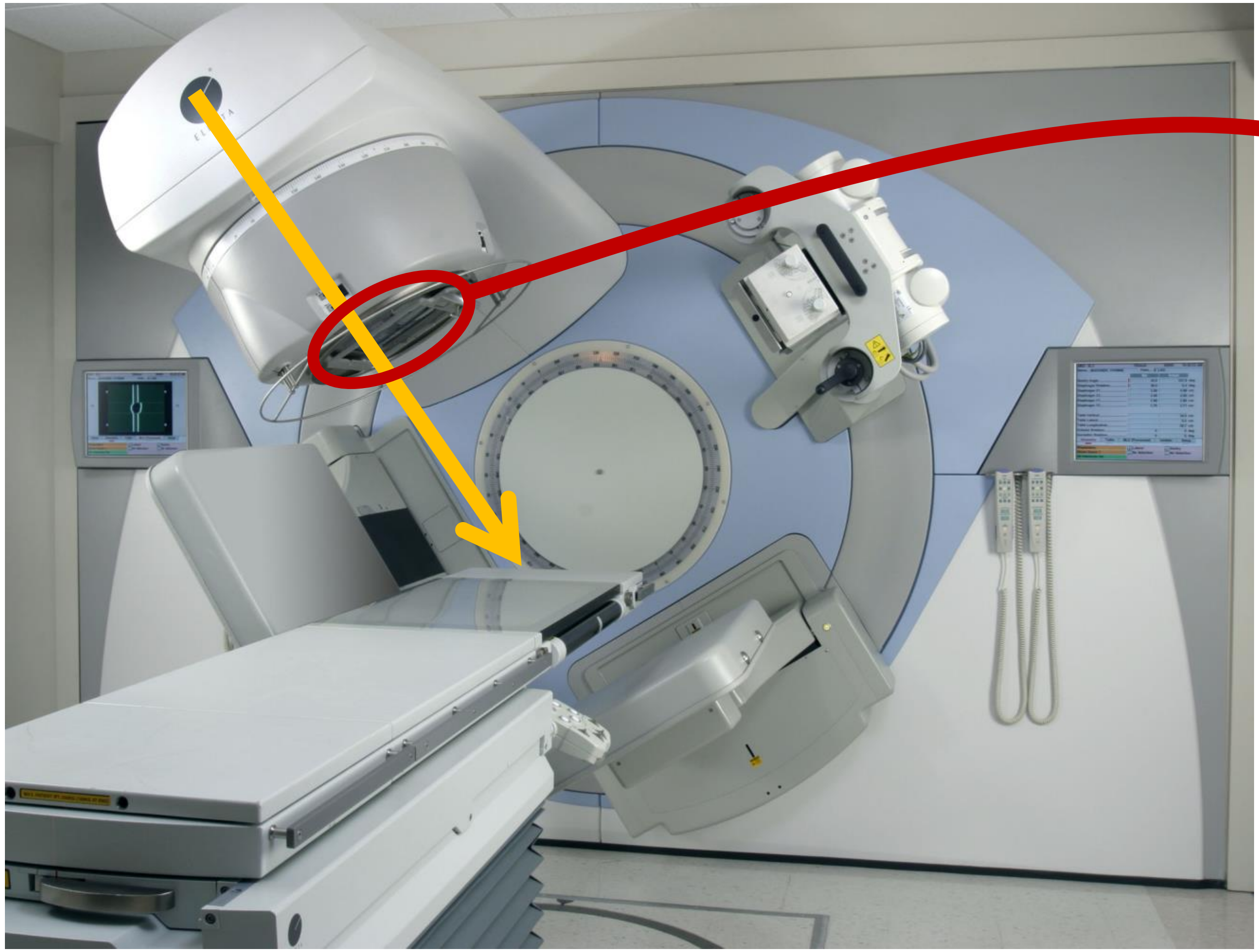
+: Relatively safe (most tissues are spared)

-: Tumor needs to be (relatively) localized

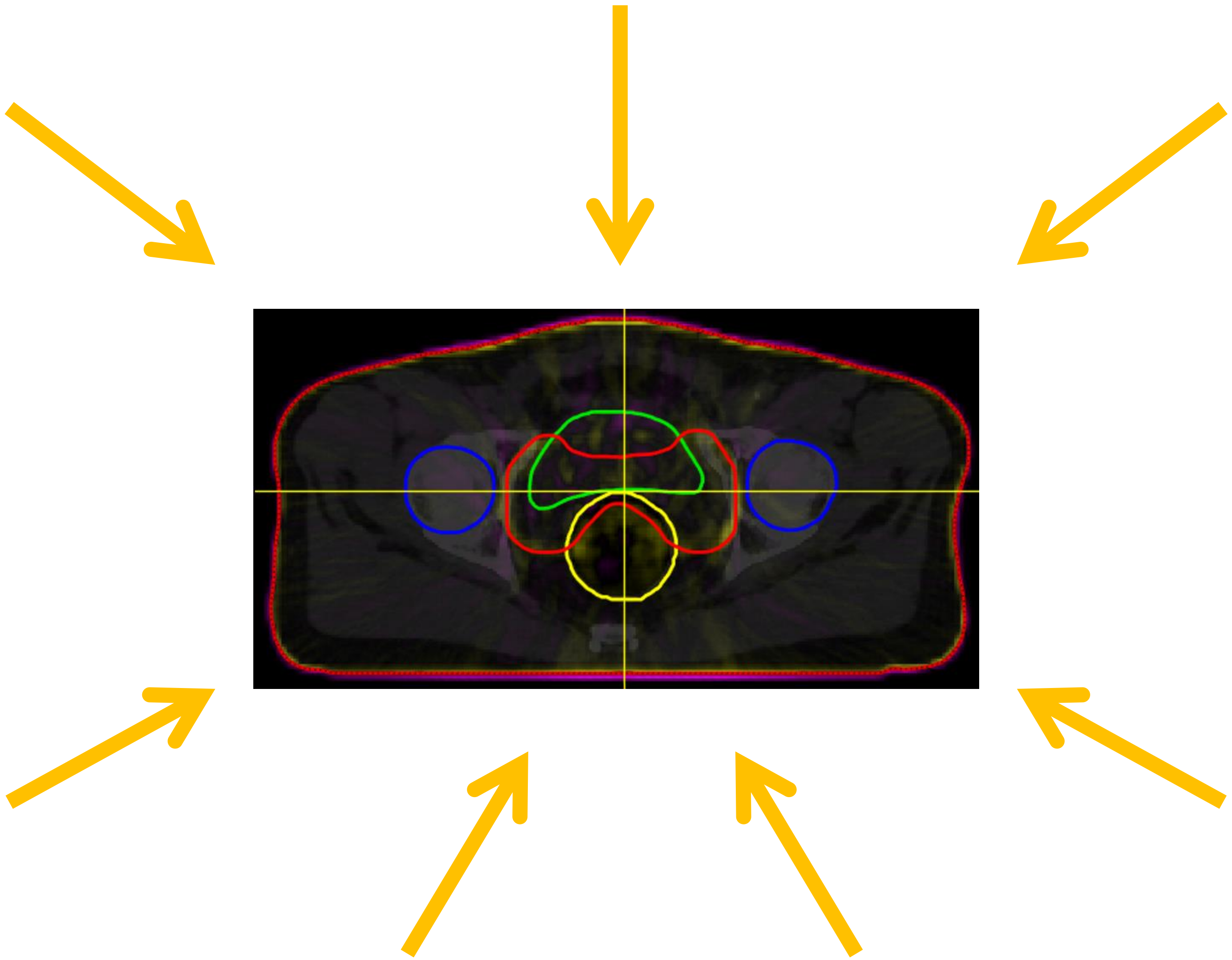
cine on all the body

s **not** need to be localized

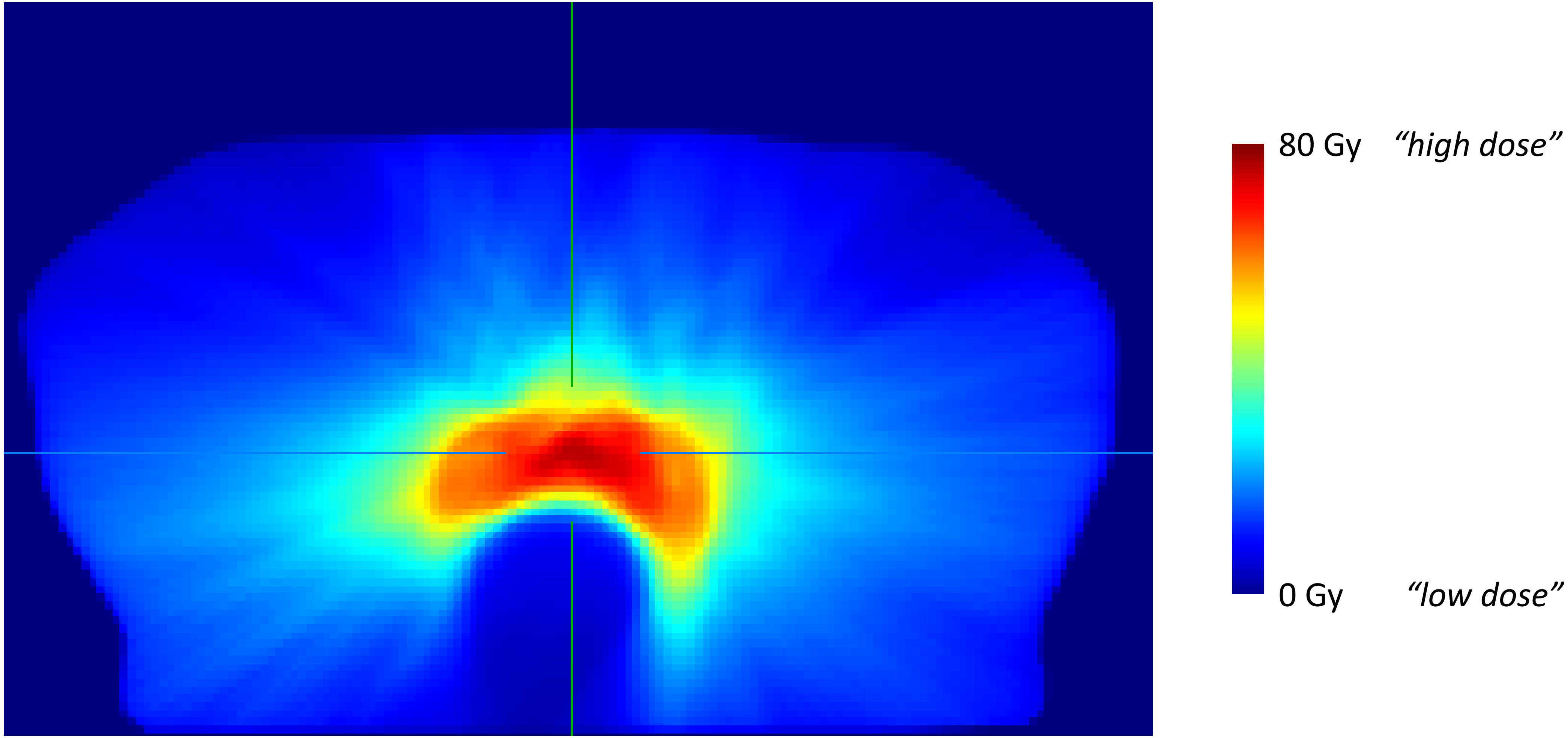
Multi-Leaf Collimator



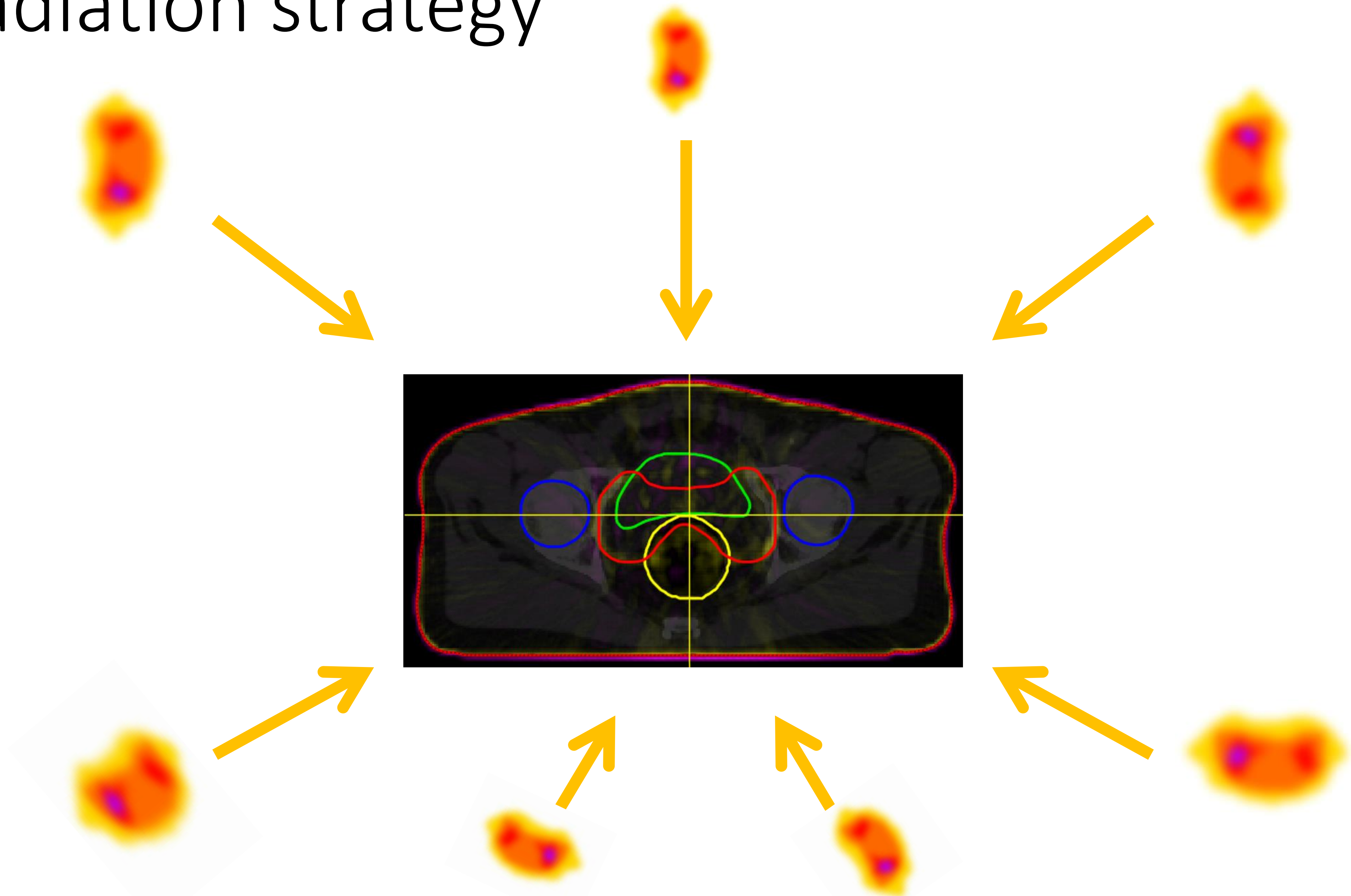
Spreading rays



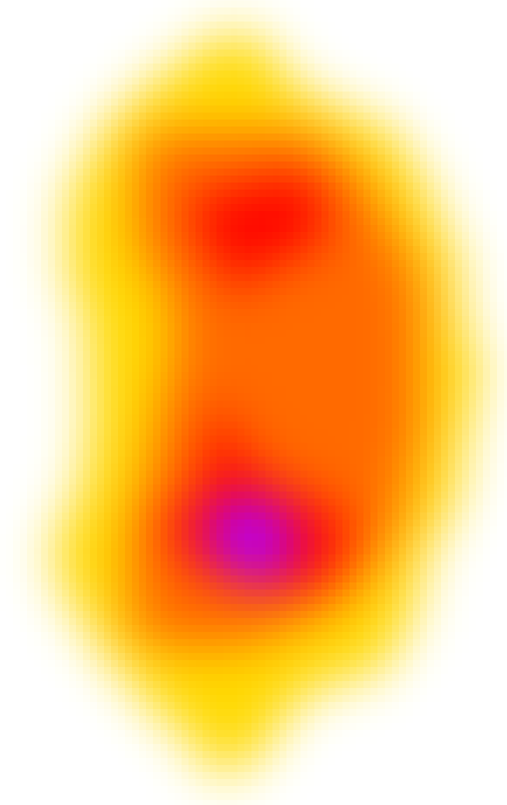
Dose Spread



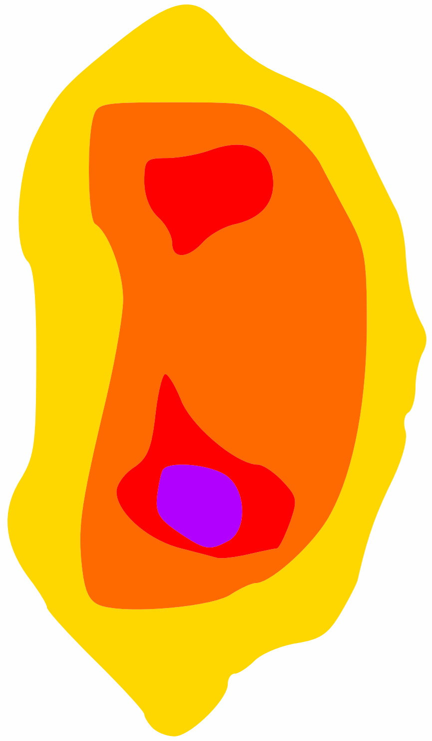
Irradiation strategy



Delivering irradiation

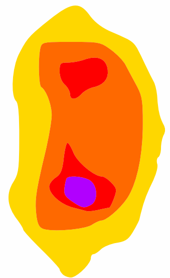


Ideal heatmap

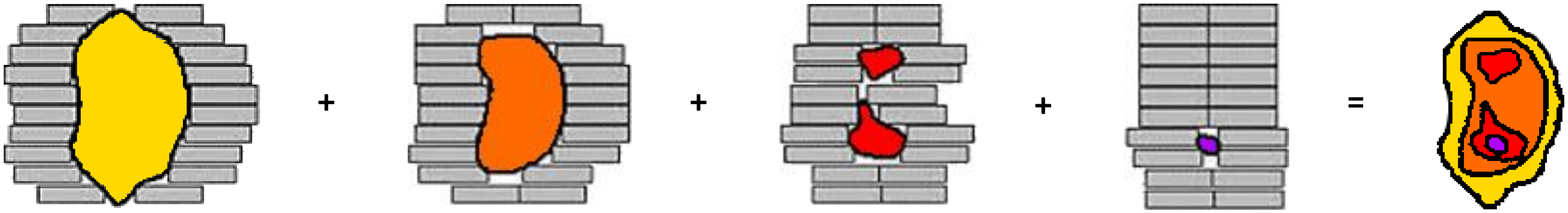


Discretized heatmap

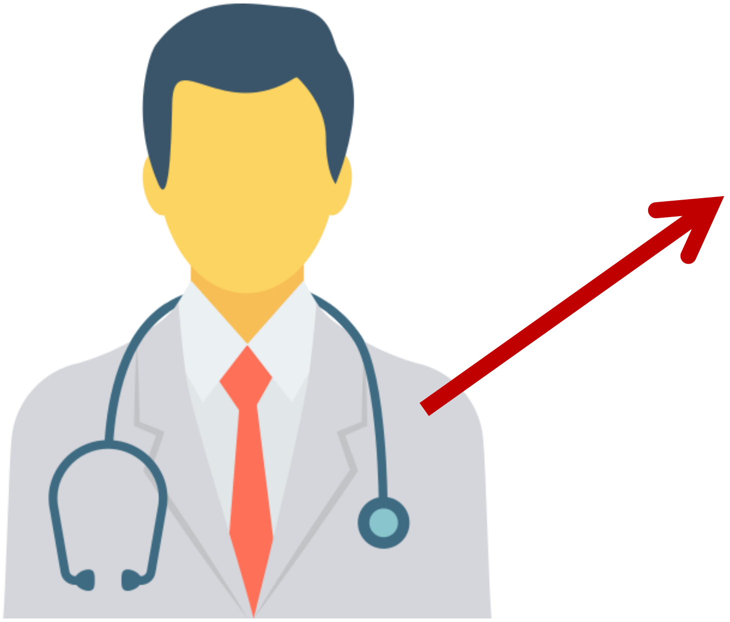
Delivering discretized dose



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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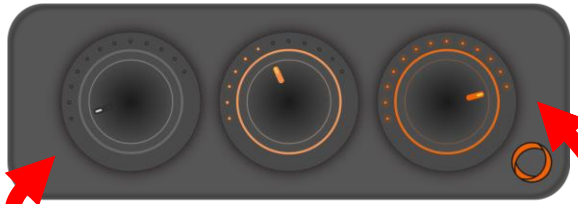


Objective function

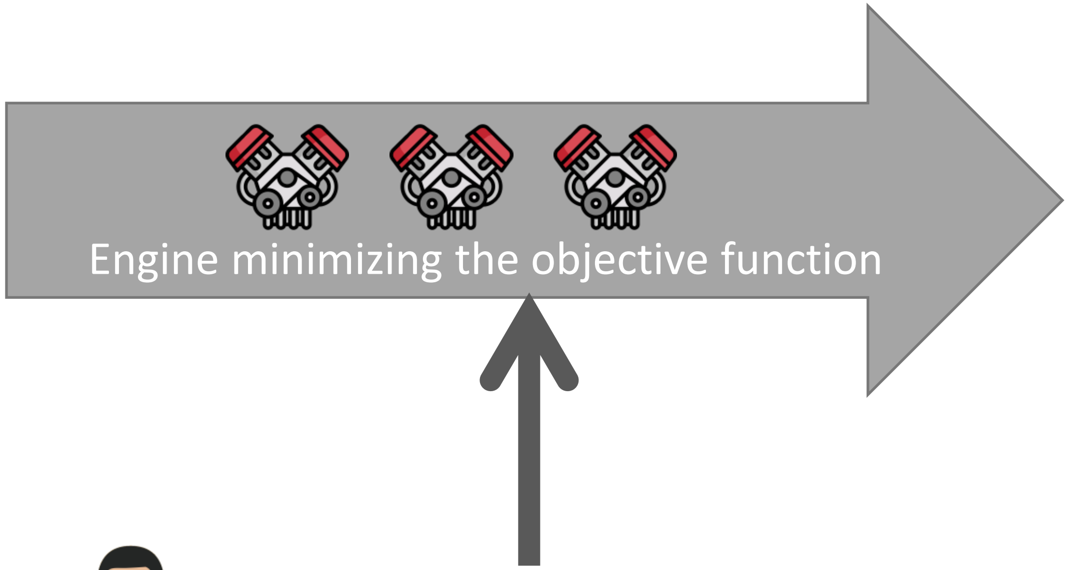
$$f_s(y) = \sum_{v \in \mathcal{V}_s} \frac{1}{|\mathcal{V}_s|} \left(\overline{w}_s (y_v - \overline{t}_s)_+^p + \underline{w}_s (-y_v + \underline{t}_s)_+^p \right)$$

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

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

Current Workflow

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

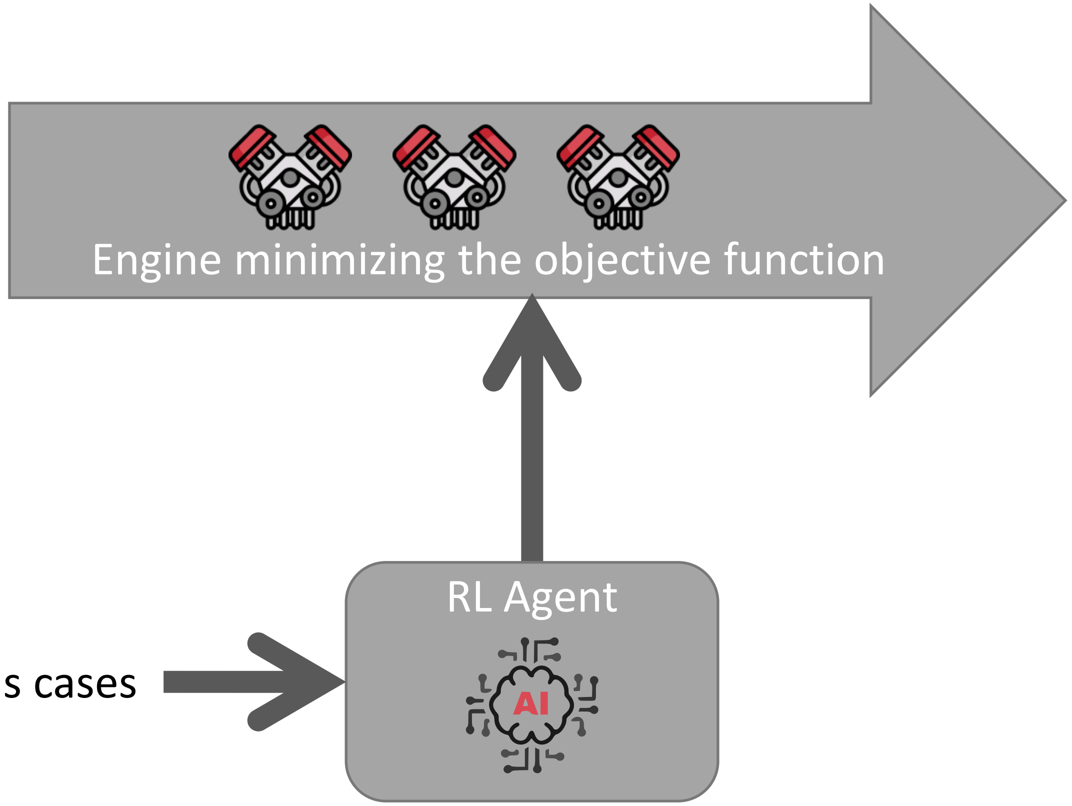


Treatment plan
- Fluences
- Leaf movements
- Dose per organ

Input from dosimetrist
- Weights of each objective

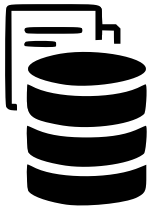
Automatization *(work in progress)*

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



Treatment plan
- Fluences
- Leaf movements
- Dose per organ

Learning based on previous cases



Thank You