Mid-PhD Defense

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Outline

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

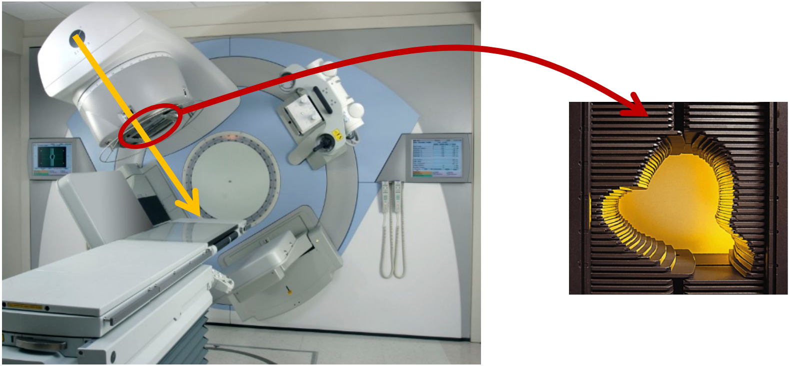
+: Relatively safe (most tissues are spared)

-: Tumor needs to be (relatively) localized

cine on all the body

s **not** need to be localized

Multi-Leaf Collimator



V-MAT Irradiation Technique

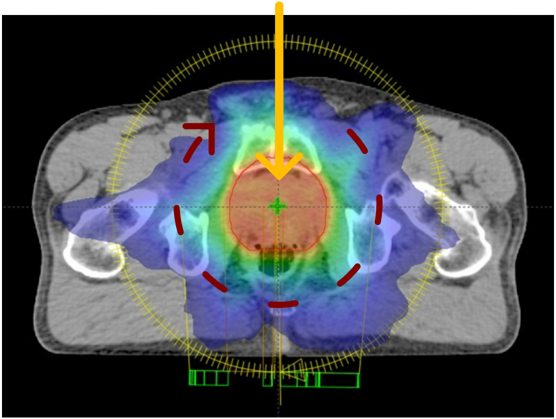


Figure: Typical V-Mat dose slice.

IMRT Irradiation Technique

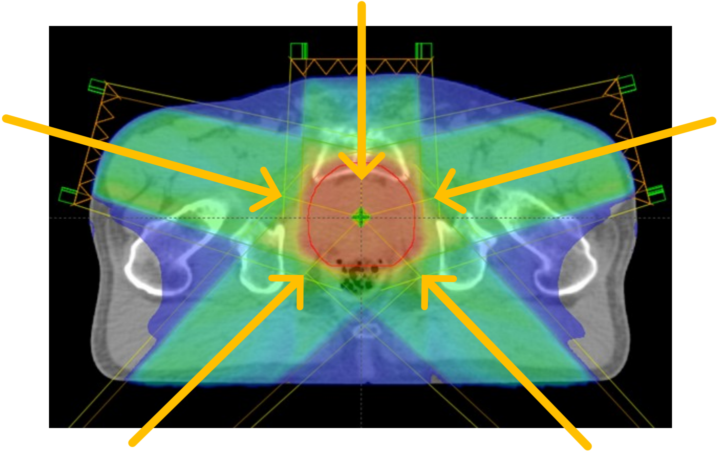


Figure: Typical 5 beams IMRT dose slice.

Step-and-Shoot (1/3)

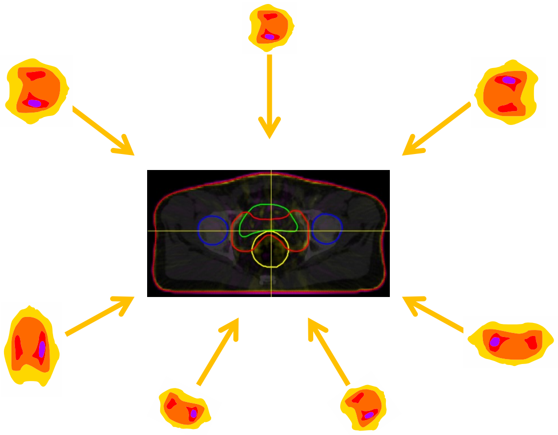


Figure: Optimal Continuous Fluence.

Step-and-Shoot (2/3)

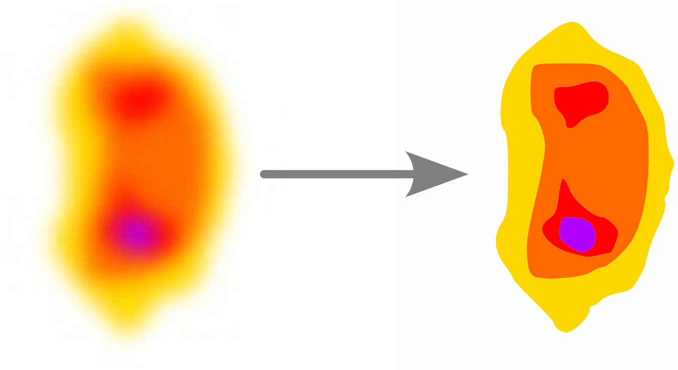


Figure: Discretizing the Fluence.

Step-and-Shoot (3/3)

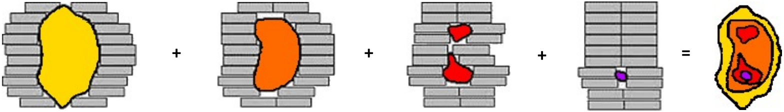


Figure: Delivering Discrete Fluence.

Sliding-Windows (1/3)

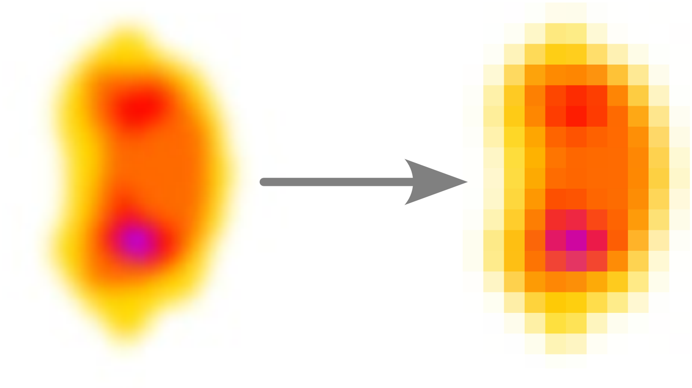


Figure: Continuous Fluence to Bixel Fluence.

Sliding-Windows (2/3)

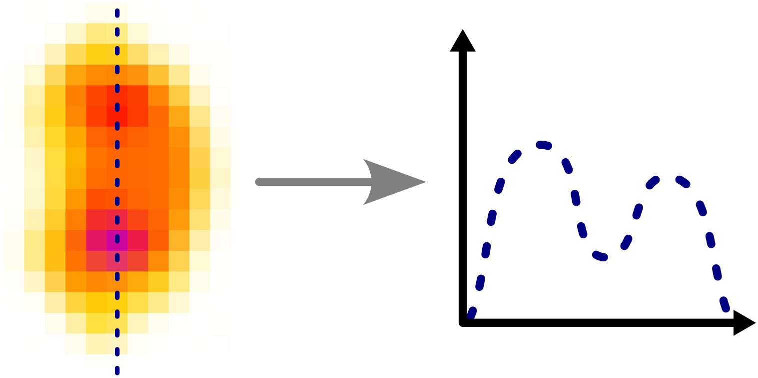


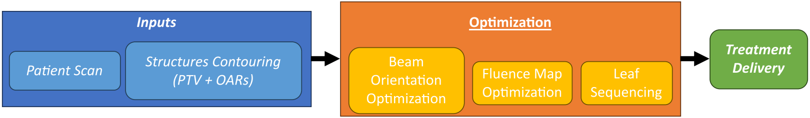
Figure: Bixel Fluence to Row/Column Curves.

Sliding-Windows (3/3)

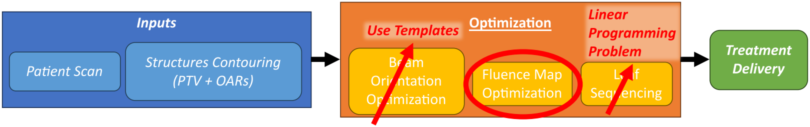
Convert rows/columns fluence curves to leafs motions.

(`https://mics-lab.github.io/PresentationJuin2023MICS/demo`)

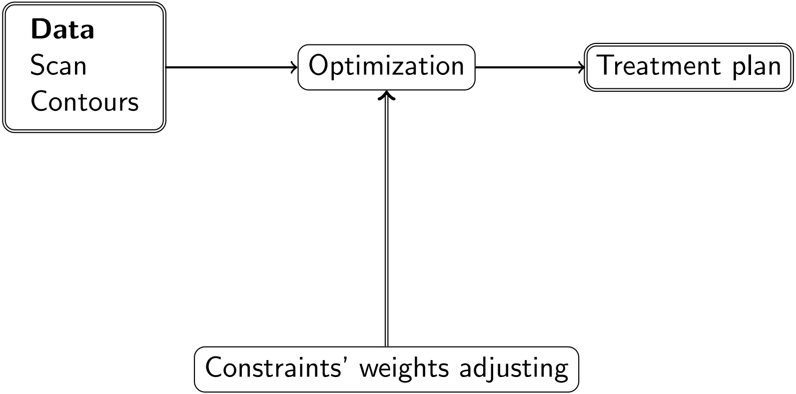
Radiotherapy Workflow



Radiotherapy Workflow



Automatic Dose Optimization for Radiotherapy



Problem Formulation
IMRT

Bixel values:

$$x_{i,j}^{\theta} \geq 0, \text{ for } \theta \in \Theta \text{ and } 1 \leq i, j \leq 20^{1}$$

usually concatenated to a single bixels-value vector x.

Dose calculation:

$$\mathbf{y} = L\mathbf{x} \text{ with } L \text{ (pre-calculated) dose-influence (DI) matrix}$$

[1] 20x20 is a typical bixel discretization

Problem Formulation

IMRT (bis)

Objective for *maximum* constraint c on structure s, dose d:

$$f_c(\mathbf{y}) = \frac{1}{|\mathcal{V}|} \sum_{v \in \mathcal{V}} (\mathbf{y}_v - d)_+^2$$

(reverse sign for minimal constraint).

Final objective:

$$f(\mathbf{y}) = \sum_{c \in \mathcal{C}} w_c f_c(\mathbf{y})$$

with w_c the weight of constraint c.

Problem Optimization

Optimizer review

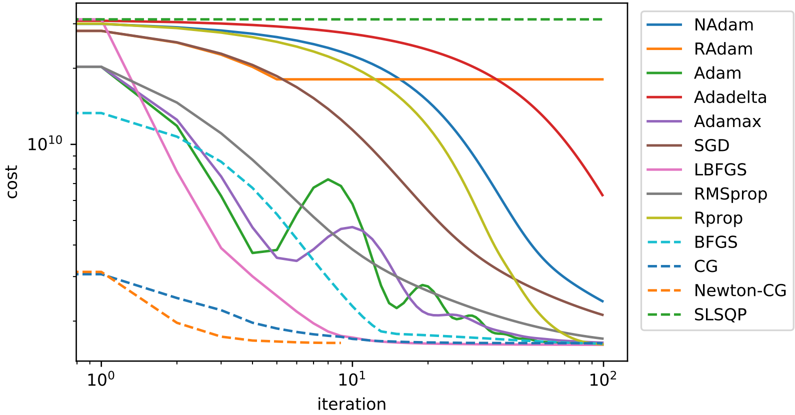


Figure: Typical prostate case.

`https://arxiv.org/abs/2305.18014`

Problem Optimization

Optimizer review (bis)

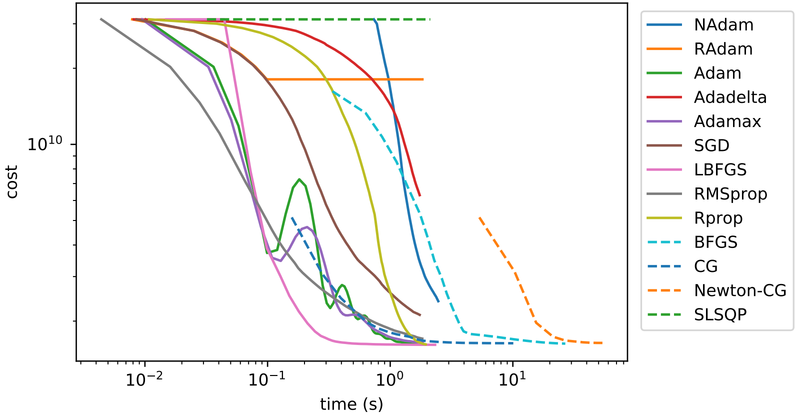


Figure: Typical prostate case.

`https://arxiv.org/abs/2305.18014`

Meta-Optimization

Usual optimization

$$\min_{\mathbf{x}} f(\mathbf{x}, w) \text{ s.t. } \mathbf{x} > 0$$

... and fine-tune w until the dose is clinically acceptable.

Meta optimization

$$\min_{w} \left\{ \min_{\mathbf{x}} f(\mathbf{x}, w) \text{ s.t. } \mathbf{x} > 0 \right\}$$

... still need to fine-tune the parameters (learning rate, momentum, etc...) of the meta-optimizer.

Dose Distances

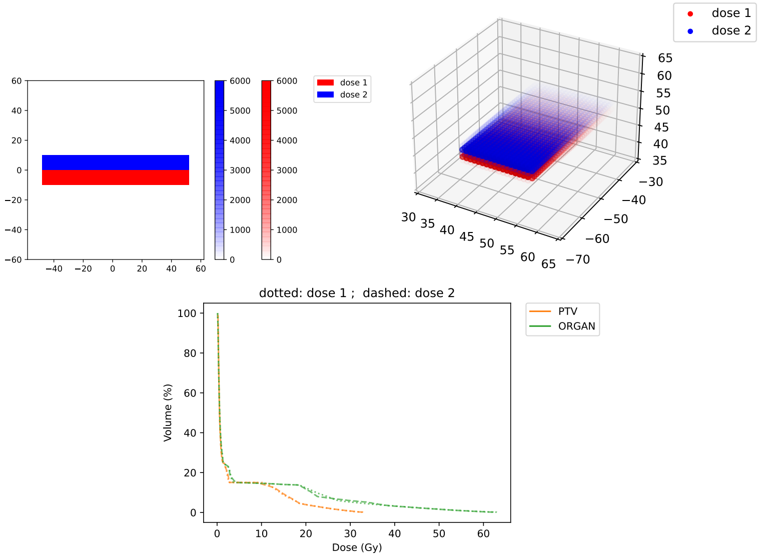
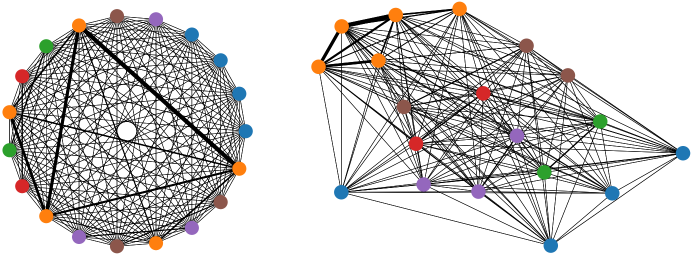


Figure: Example of two doses that have the same clinical effect (measured from the DVHs), but very different voxel-wise dose values.

Dose Clustering



(a) (Circular Layout)   (b) (Spring Layout)

Figure: Doses Network

edges width $\propto$ edge weight $\propto$ ${}^{1}\!/_{\text{distance}}$

node's color reflects community attribution

Dose Clustering

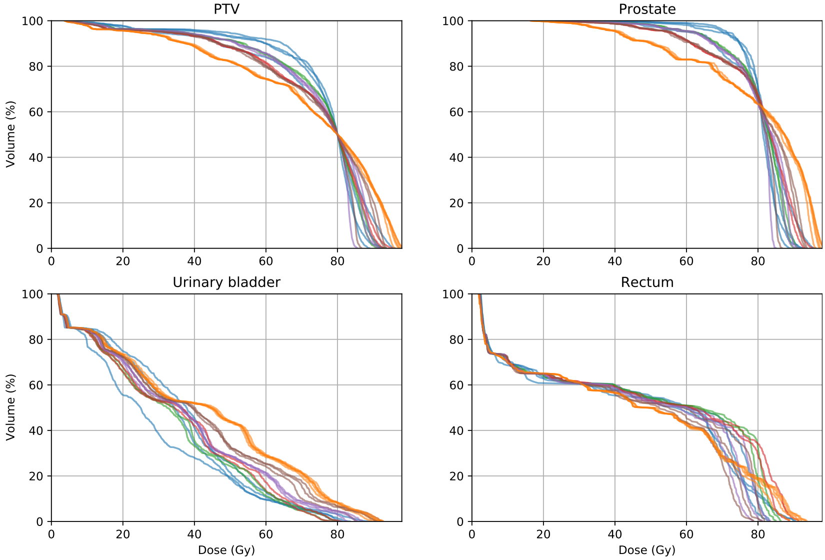


Figure: Dose-Volume Histogram

Dose Clustering

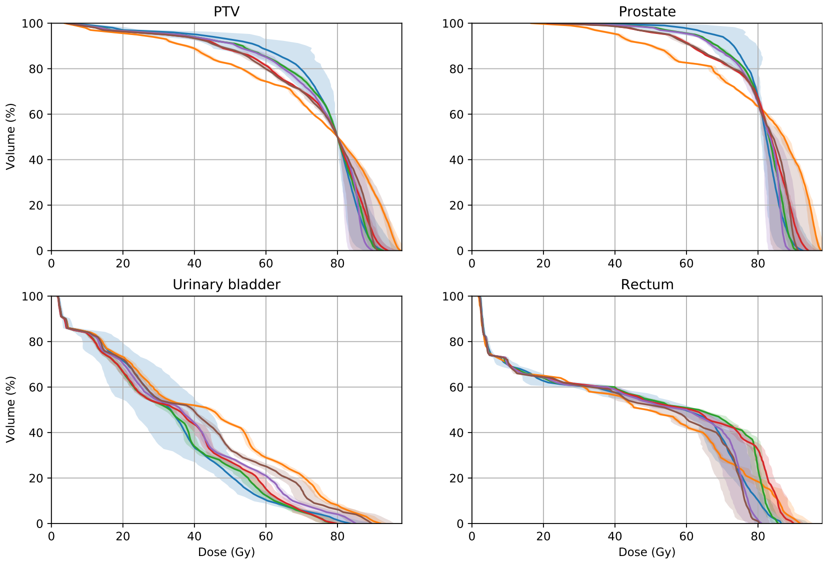
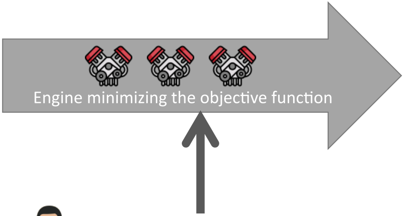


Figure: Dose-Volume Histogram Standard Deviation per Community

Current Workflow

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



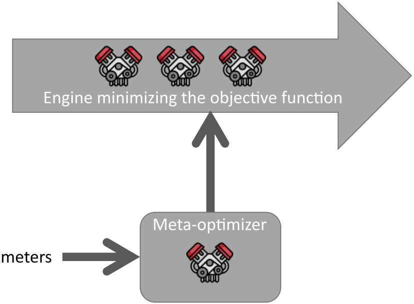
Treatment plan
- Fluences
- Leaf movements
- Dose per organ

Input from dosimetrist
- Weights of each objective

1st Automatization try *“baseline”*

Patient data

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



Treatment plan

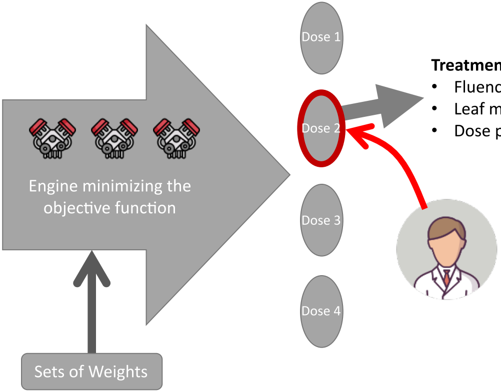
- Fluences
- Leaf movements
- Dose per organ

Fine tuning of hyper parameters

1^{st} (bis) Automatization try

Patient data

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

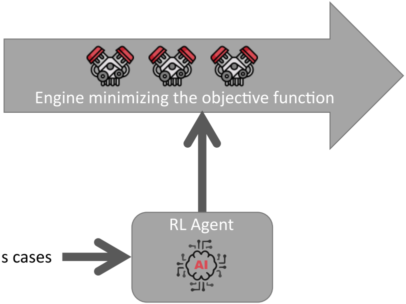


Treatment plan

- Fluences
- Leaf movements
- Dose per organ

2nd Automatization try *(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

Teaching

Lectures:

- Mathematics Refresher Course for DSBA (M2 students) 2021
- Deep Learning for HSB (3^{rd} year students) 2023

TDs:

- Coding Weeks (1^{st} year) 2021
- Optimization (1^{st} year) 2021
- Visual recognition (3^{rd} year) 2022
- Coding Weeks (1^{st} year) 2022
- Algorithm and Complexity (2^{nd} year) 2022/2023

Doctoral Training

- ED INTERFACES - Journée de Rentrée 2022 le 12 janvier 2023 (14 décembre 2022)
- Math On Mars (06 mai 2022) Info@lèze
- Asymmetric Cryptography (23 septembre 2022) Info@lèze
- Genetic Algorithms (10 juin 2022) Info@lèze
- Math With Jupyter (18 décembre 2021) Info@lèze
- Writing skills in Science ADVANCED [Eng] (10 mai 2022)
- AI 4 Health (10 janvier 2022 - 14 janvier 2022) Emmanuel Bacry

Total participation : 109 heures / 7 modules
Total des Crédits/Points de Thèse : 22

References

Dinesh Kumar Mynampati, Ravindra Yaparpalvi, Linda Hong, Hsiang-Chi Kuo, and Dennis Mah.
Application of aapm tg 119 to volumetric arc therapy (vmat).
Journal of Applied Clinical Medical Physics, 13(5):108–116, 2012.