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A general multi-criteria approach for iterative (re)optimization

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Introduction

Treatment planning is a *multi-criteria* problem.

Generally this problem is handled by manually adapting the importance factors for the organs involved, to meet treatment constraints.

Modern algorithms automatically optimize importance factors to meet the treatment constraints.

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- the constraints can be too *strict*
- the constraints can be too *loose*

Resulting plan will be *suboptimal*, or even *unacceptable* if some constraints are not met.

Manually finding these constraints is very time-consuming.

We propose a method to automatically optimize treatment constraints.

Optimizing Constraints

Our method is to find a set of constraints with the following properties:

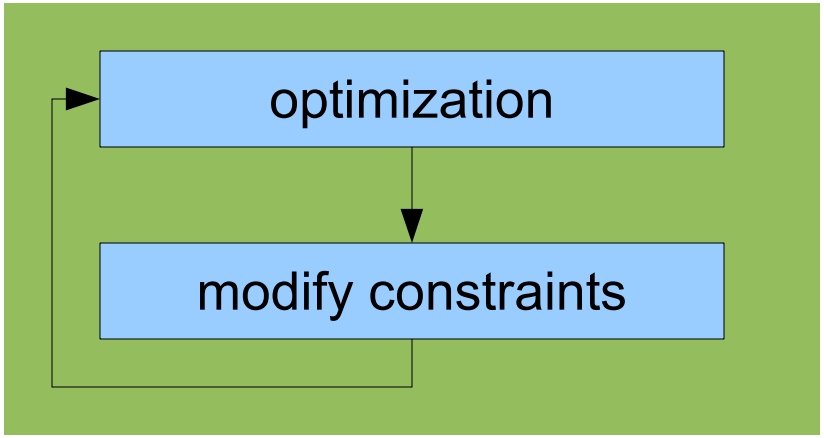
- the final plan satisfies all hard constraints
- the set is Pareto optimal

Optimizing Constraints

The process of finding constraints has been automized.

A *constraint list* helps in sorting the importance of meeting a constraint.

A multi-criteria algorithm uses this list to optimize the constraints. This is *independent* of the underlying optimization algorithm (fluence map, beam angle, wedges, etc.)



Constraint list

Typical constraint list for rectum cancer with a prescribed dose of 44.65 Gy.

constaint nr	volume	type	critical	objective	priority
1	PTV	DV	42.42 Gy	100%	0
2	PTV	Max		47.78 Gy	0
3	Body	Max		47.78 Gy	0
4	Bowel	DV	35 Gy	20%	1
5	Bladder	DV	40 Gy	40%	2
6	Colon	DV	40 Gy	20%	2
7	Bowel	DV	20 Gy	50%	3
8	Bladder	DV	20 Gy	75%	3
9	Colon	DV	20 Gy	30%	3
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5	Bladder	DV	40 Gy	10%	0%	2
6	Colon	DV	40 Gy	20%	0%	2

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1	PTV	DV	42.42 Gy	100%	100%	0
2	PTV	Max		47.78 Gy	47.12	0
3	Body	Max		47.78 Gy	44.79	0
4	Bowel	DV	35 Gy	20%	28.83%	1
5	Bladder	DV	40 Gy	10%	14.86%	2
6	Colon	DV	40 Gy	20%	8.30%	2

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5	Bladder	DV	40 Gy	15%	14.15%	2
6	Colon	DV	40 Gy	20%	8.26%	2

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1	PTV	DV	42.42 Gy	100%	100%	0
2	PTV	Max		47.78 Gy	47.23	0
3	Body	Max		47.78 Gy	45.08	0
4	Bowel	DV	35 Gy	27%	26.04%	1
5	Bladder	DV	40 Gy	15%	14.15%	2
6	Colon	DV	40 Gy	20%	8.21%	2

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4	Bowel	DV	35 Gy	26%	25.00%	1
5	Bladder	DV	40 Gy	15%	14.06%	2
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4	Bowel	DV	35 Gy	24%	24.15%	1
5	Bladder	DV	40 Gy	15%	13.97%	2
6	Colon	DV	40 Gy	20%	8.09%	2

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5	Bladder	DV	40 Gy	14%	12.81%	2
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5	Bladder	DV	40 Gy	14%	12.81%	2
6	Colon	DV	40 Gy	8%	8.06%	2

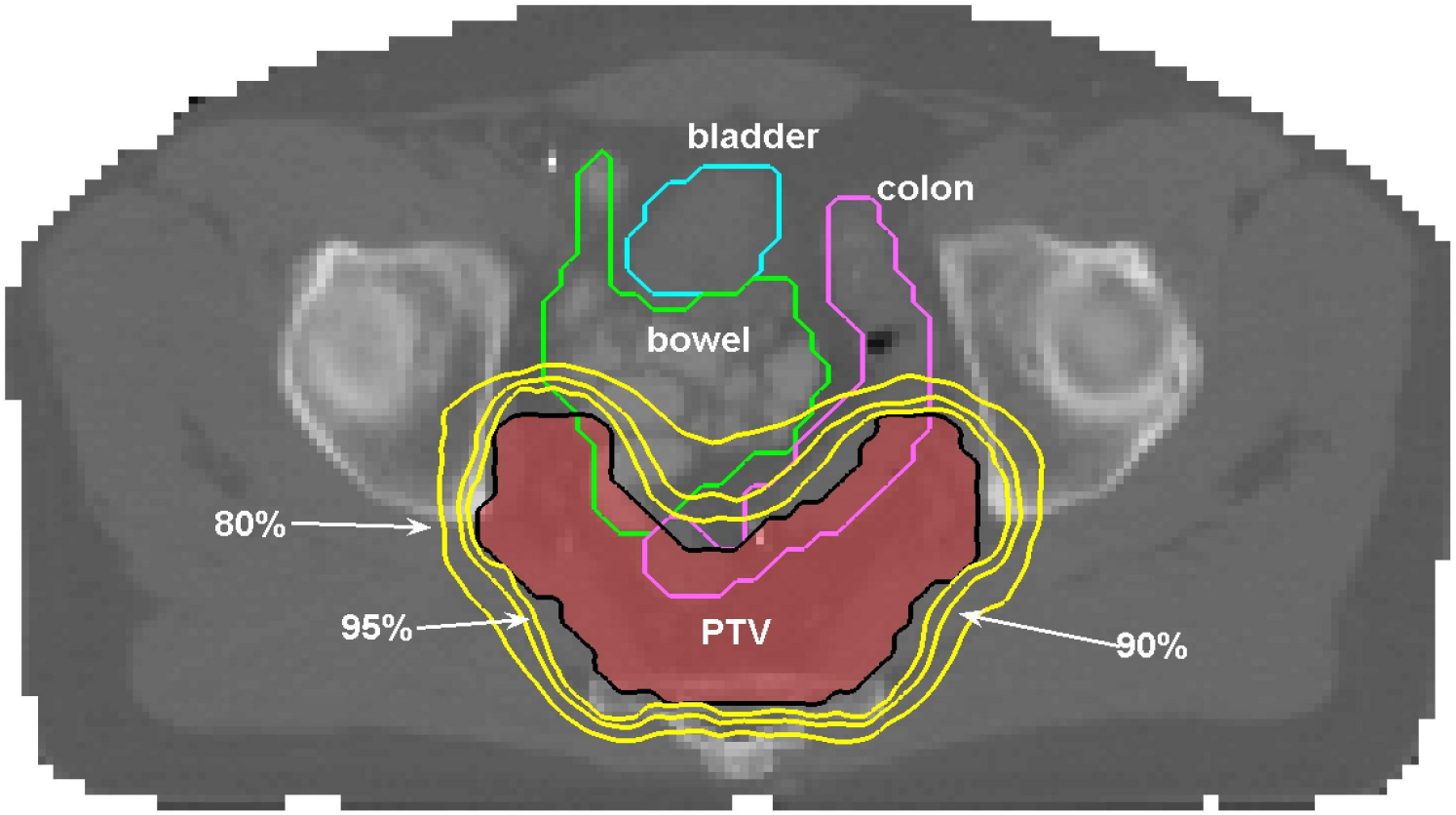
This process is repeated until none of the constraints can be fastened anymore.

Result for the rectum

constaint nr	volume	type	critical	objective	result obj.	priority
1	PTV	DV	42.42 Gy	100%	100%	0
2	PTV	Max		47.78 Gy	47.77 Gy	0
3	Body	Max		47.78 Gy	46.36 Gy	0
4	Bowel	DV	35 Gy	20%	24.3%	1
5	Bladder	DV	40 Gy	40%	10.0%	2
6	Colon	DV	40 Gy	20%	7.6%	2
7	Bowel	DV	20 Gy	50%	36.2%	3
8	Bladder	DV	20 Gy	75%	25.0%	3
9	Colon	DV	20 Gy	30%	12.6%	3
10	Body	DV	30 Gy	40%	17.8%	4

Optimization algorithm used is a fluence map optimization which iteratively adapts voxel-dependent importance factors in a quadratic objective function.

A result



Note: result is still subjective to the used optimization algorithm, but tight constraints enforce conformity.

Class solutions

A constraint list is very suitable for generalization of a treatment planning.

Can a single constraint list be used as a class solution?

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8	Bladder	DV	20 Gy	75%	3
9	Colon	DV	20 Gy	30%	3
10	Body	DV	30 Gy	40%	4

Class solution: Rectum

- the constraint list was tuned on 4 patients
- this is verified on 4 other patients
- mean results are compared with the clinical plan (CadPlan)

		bowel	bladder	colon
tuning group	1	23%	18%	4%
	2	10%	5%	22%
	3	5%	11%	15%
	4	13%	47%	17%
verification group	5	11%	14%	5%
	6	9%	6%	10%
	7	10%	10%	-5%
	8	4%	18%	37%
average		10%	16%	13%
standard deviation		6%	14%	13%

Conclusion

- optimizing treatment constraints by a prioritized constraint list is a powerful tool for multi-criteria treatment planning
- a properly tuned constraint list makes it possible to achieve good results in an automated process