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A multi-criteria approach for generation of a single solution

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Today's problems

- ideal plan does not exist ➔ treatment plan is a compromise
- which criteria offers the best compromise for an individual patient?
  for a group of patients?

- too strict criteria ➔ no solution
- too loose criteria ➔ suboptimal solution
- treatment planning often based on choosing weights ➔ indirect
- mixture of objectives/criteria and constraints

Traditional planning is time-consuming because the physician has to find the compromise manually by adjusting weights and/or criteria.

This is a bad use of resources (people) because the majority of the cases are routine cases.

Today's problems

This is a bad use of resources (people) because the majority of the cases are routine cases.

For these cases, protocols with weights, prescriptions, criteria, etc. exist to facilitate planning.

But what do we really want

What do we want?

The radiation oncologist constructs a 'wish-list' with:

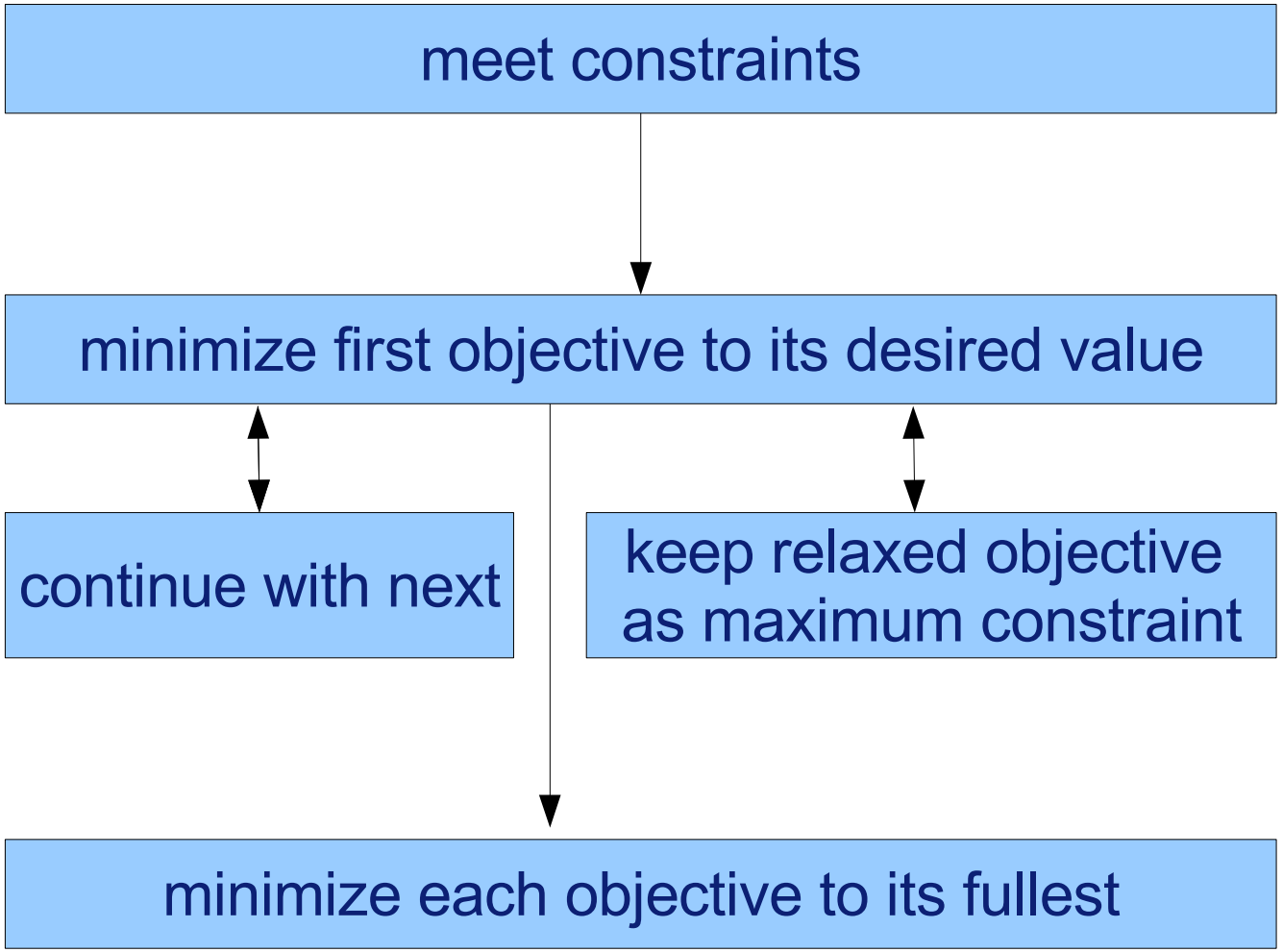
- constraints
- objectives
- priority of meeting each objective

This results in a plan where:

- constraints are always satisfied
- objectives are met as well as possible
- each objective is minimized to its fullest

Note that this results in a single solution (in contrast to other multi-criteria approaches)

3 stage multi-criteria optimization



Example

	Objective	Priority
PTV	95%-107% prescribed dose	0
Spinal Cord	max 45 Gy	0
Left Parotid	mean < 26 Gy	1
Right Parotid	mean < 26 Gy	2
Trachea	mean < 40 Gy	3
Body	dosis-volume 30 Gy < 100%	4

Example

- Stage 1, meet constraints

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	
Right Parotid	mean < 26 Gy	2	
Trachea	mean < 40 Gy	3	
Body	dosis-volume 30 Gy < 100%	4	

Example

- Stage 2, Left Parotid

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	26 Gy
Right Parotid	mean < 26 Gy	2	
Trachea	mean < 40 Gy	3	
Body	dosis-volume 30 Gy < 100%	4	

Example

- Stage 2, Right Parotid

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	26 Gy
Right Parotid	mean < 26 Gy	2	34 Gy
Trachea	mean < 40 Gy	3	
Body	dosis-volume 30 Gy < 100%	4	

Example

- Stage 2, Trachea

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	26 Gy
Right Parotid	mean < 26 Gy	2	34 Gy
Trachea	mean < 40 Gy	3	40 Gy
Body	dosis-volume 30 Gy < 100%	4	

Example

- Stage 2, Body

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	26 Gy
Right Parotid	mean < 26 Gy	2	34 Gy
Trachea	mean < 40 Gy	3	40 Gy
Body	dosis-volume 30 Gy < 100%	4	100%

Example

- Stage 3, redo Left Parotid

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	26 ➔ 21 Gy
Right Parotid	mean < 26 Gy	2	34 Gy
Trachea	mean < 40 Gy	3	40 Gy
Body	dosis-volume 30 Gy < 100%	4	100%

Example

- Stage 3, redo Trachea

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	21 Gy
Right Parotid	mean < 26 Gy	2	34 Gy
Trachea	mean < 40 Gy	3	40 → 39 Gy
Body	dosis-volume 30 Gy < 100%	4	100%

Example

- Stage 3, redo Body

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	21 Gy
Right Parotid	mean < 26 Gy	2	34 Gy
Trachea	mean < 40 Gy	3	39 Gy
Body	dosis-volume 30 Gy < 100%	4	100 → 18%

Example

- Final Result

	Objective	Priority	Result
PTV	95%-107% prescribed dose	0	met
Spinal Cord	max 45 Gy	0	met
Left Parotid	mean < 26 Gy	1	21 Gy
Right Parotid	mean < 26 Gy	2	34 Gy
Trachea	mean < 40 Gy	3	39 Gy
Body	dosis-volume 30 Gy < 100%	4	18%

Advantages

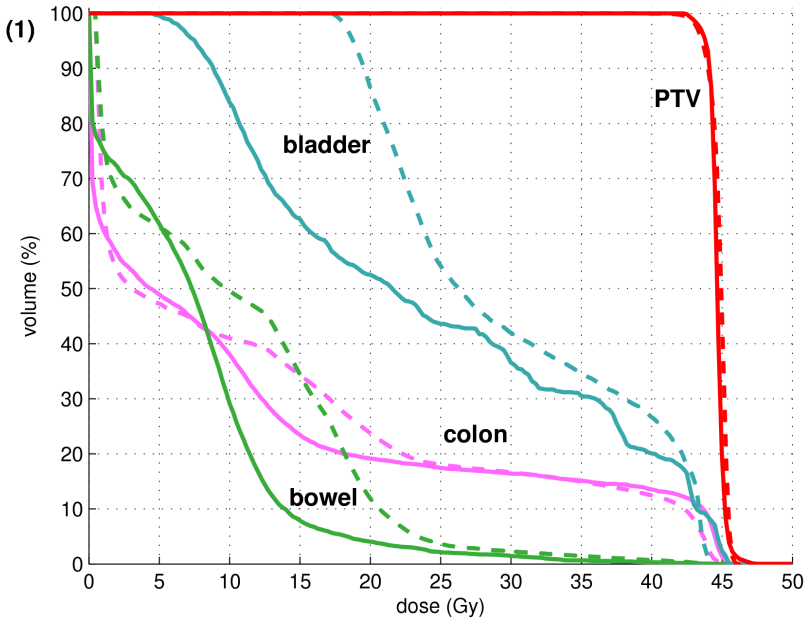
- implementation of the ε-constraint method ➔ Pareto optimal solution
- no human intervention during and after planning
- strict distinction between objectives and constraints
- the second stage allows the algorithm to meet lesser important objectives when more important objectives are met
- wish list can be used as a class-solution

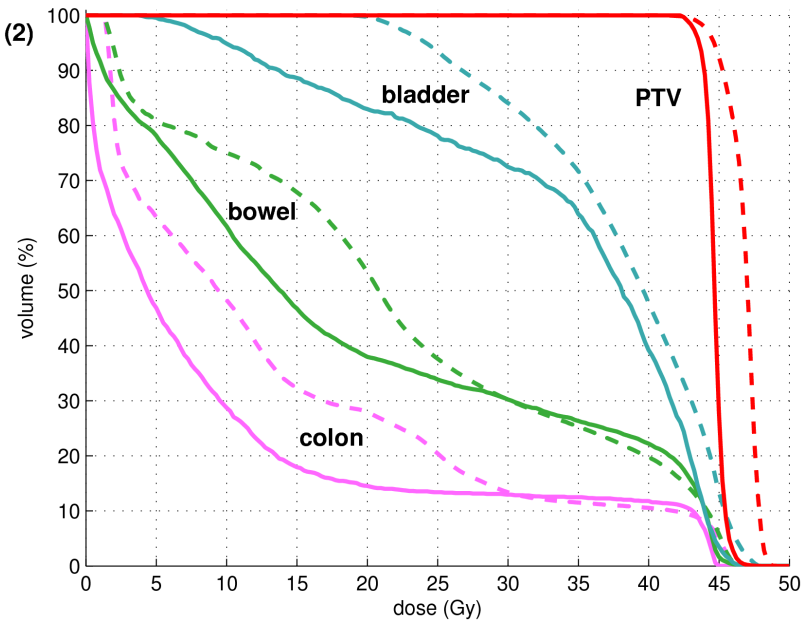
Class solutions

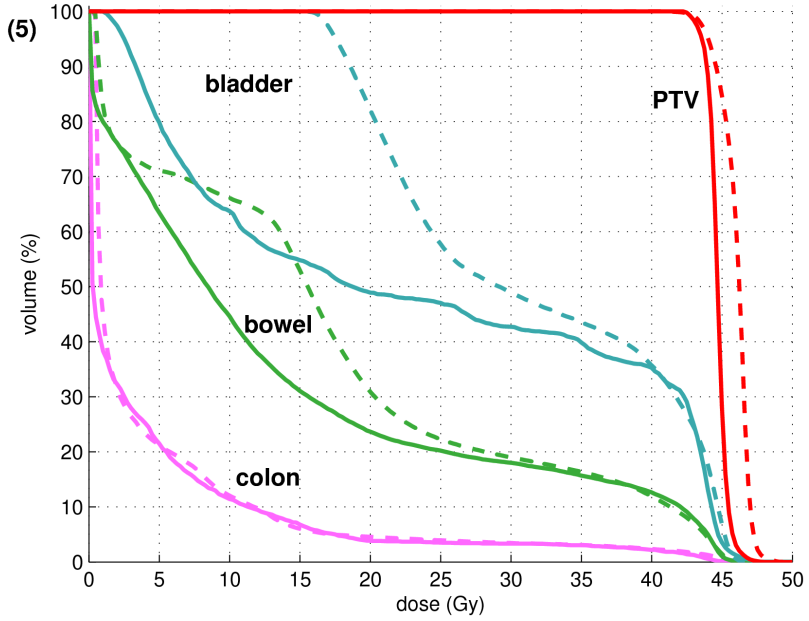
A well defined list of constraints (wish-list) can be used as a class solution.

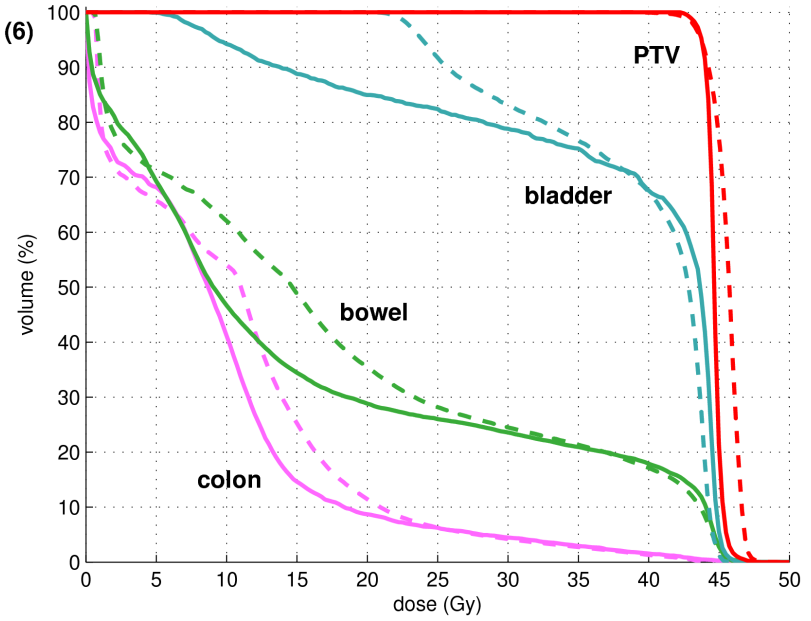
Research on 8 rectum patients and 5 oropharynx patients show structural and significant improvements.

Class solutions: rectum









Complex head and neck case

No	Volume	Constraint type	Critical dose	Objective	Realized objective	Mean dose	Clinical realized objective	Constraint set
1	PTV46	DV	43.7 Gy	100%	100.0%		96.5%	0
2	Sella	Max		55 Gy	55.0 Gy		52.6 Gy	0
3	Myelum	Max		45 Gy	44.8 Gy		51.6 Gy	0
4	Optic chiasm	Max		50 Gy	50.0 Gy		52.5 Gy	0
5	Optical nerve (L)	Max		55 Gy	55.0 Gy		47.3 Gy	0
6	Optical nerve (R)	Max		55 Gy	52.0 Gy		48.5 Gy	0
7	Eye (L)	Max		35 Gy	35.0 Gy		42.9 Gy	0
8	Eye (R)	Max		35 Gy	35.0 Gy		42.5 Gy	0
9	PTV70	Max		74.9 Gy	74.8 Gy		78.9 Gy	0
10	PTV70	DV	66.5 Gy	100%	93.2%		89.1%	1
11	Brainstem	DV	55 Gy	0%	0.0%		1.2%	2
12	Pons	DV	55 Gy	0%	0.0%		2.9%	2
13	Parotid (L)	DV	26 Gy	50%	46.1%	27.0 Gy	39.2%	3
14	Oral cavity	DV	26 Gy	50%	48.0%	30.2 Gy	100.0%	4
15	Pharynx/trachea	DV	40 Gy	40%	24.2%	34.5 Gy	44.3%	4
16	Lung tops	DV	18 Gy	20%	6.5%	6.5 Gy	20.0%	4
17	Body	DV	40 Gy	90%	18.9%		N/A[a]	5

[a] Definition of (external) body contour differs between CadPlan and our algorithm.

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8	Eye (R)	Max					42.5 Gy	0
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objective for PTV because of overlap with chiasm

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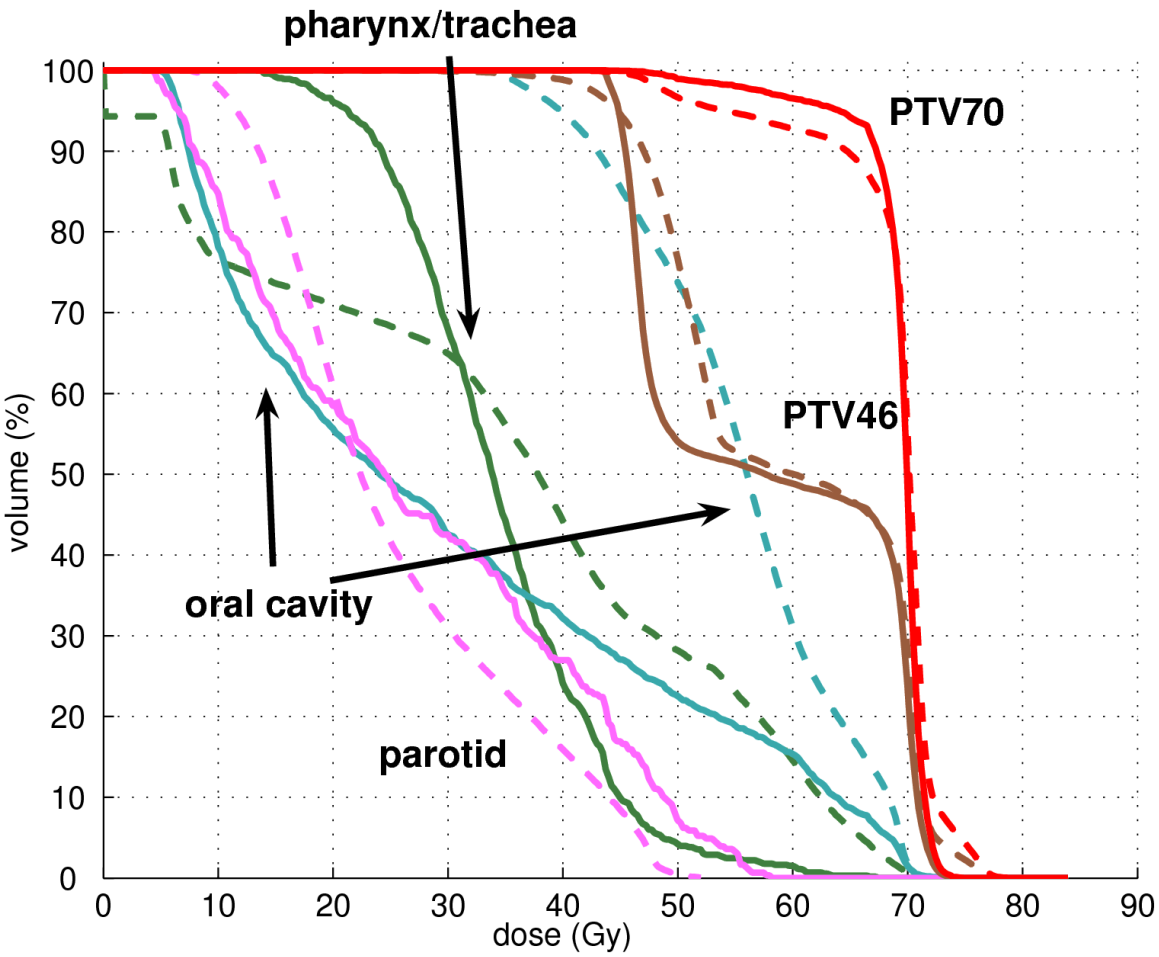
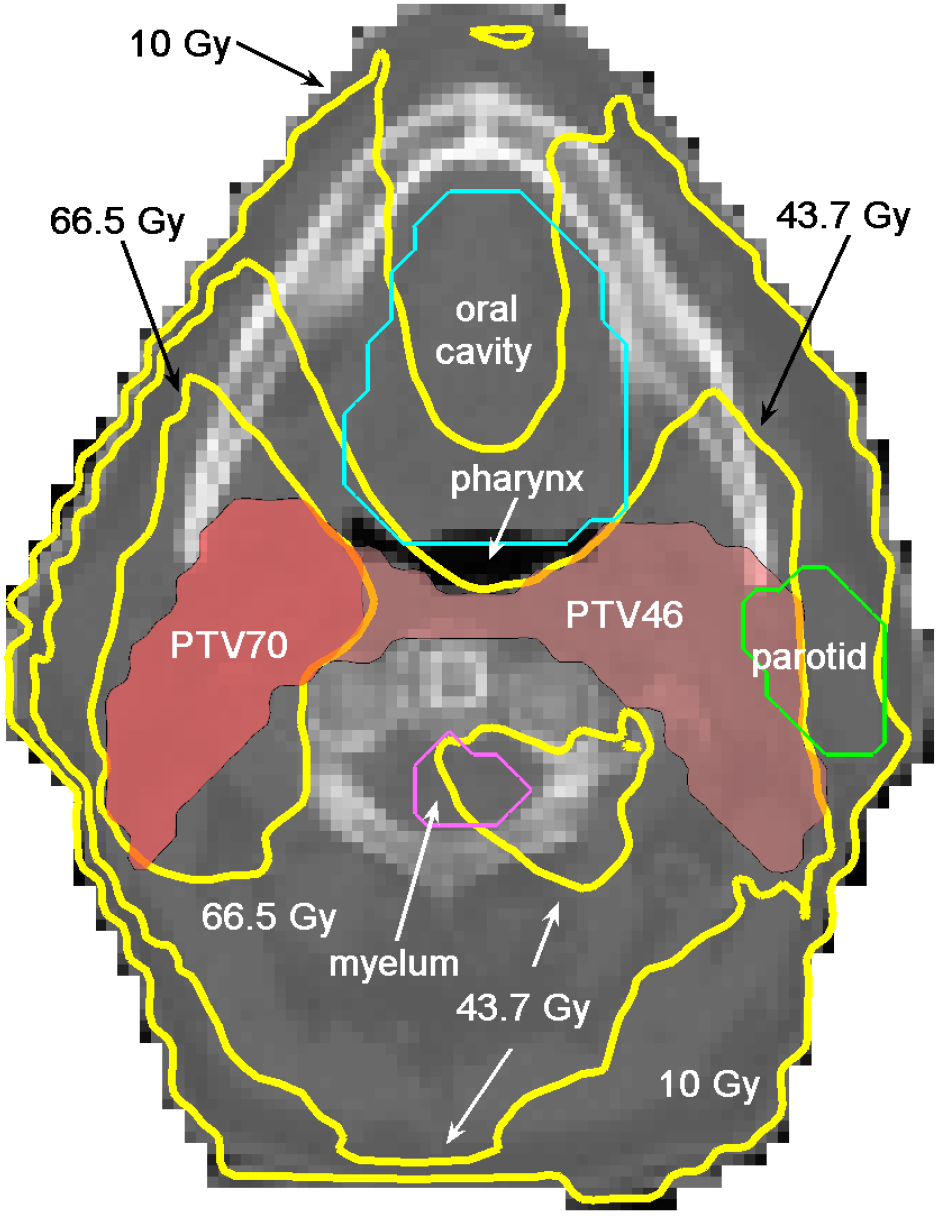
Complex head and neck case



Complex head and neck case



Summary and conclusions

Contemporary treatment planning is time-consuming and based on indirect measures.

Advantages of a wish-list in combination with the 3-stage multi-criteria algorithm:

- input is information of what the radiation oncologist really wants
- can be used as a class-solution
- is fully automated ➔ reduces human interaction
- offers a Pareto optimal solution
- is shown to be superior to human trail-and-error planning

A novel approach to multi-criteria inverse planning for IMRT

Breedveld *et al*, Phys. Med. Biol. 52 (2007), 6339-6353