Important notice!

The work presented here had excellent results on simple sites with few objectives.

Unfortunately, when generalizing to complex cases with more objectives, the method of fast re-planning using Lagrangian multipliers behaved unpredictably. Not too bad, but also not good enough for clinical application.

As such, this presentation is useful to learn about what does not work.

Sorry!
A fast and accurate automated method for online re-planning in adaptive radiotherapy

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Thanks to Theodore Mutanga, Peter Voet and Suzanne Leinders

ICCR 2010 Amsterdam

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Workflow

- plan on planning CT
- make daily in-room CT scan
- use Fast optimization on daily CT
- check and apply plan each fraction
Fast optimization

Reduce human interaction

Automate treatment planning
Multi-criteria optimization

- Use a **wish-list**, a prescription list with constraints and goals.
- Automates **decision making**.
- Gives a **single Pareto-optimal plan**.
- 2-phase **ε-constraint optimization strategy**.
- **Wish-list** used as a **template**.
- Plans are **clinically relevant**.

## Wish-list: cervix-uterus boost

### Constraints

<table>
<thead>
<tr>
<th>Nr</th>
<th>Volume</th>
<th>Type</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cervix-uterus (CTV)</td>
<td>maximum</td>
<td>80 $Gy$</td>
</tr>
<tr>
<td>2</td>
<td>CTV Conformity Ring</td>
<td>maximum</td>
<td>62.9 $Gy$</td>
</tr>
<tr>
<td>3</td>
<td>Bladder - CTV+10mm</td>
<td>maximum</td>
<td>70 $Gy$</td>
</tr>
<tr>
<td>4</td>
<td>External - 50mm Ring</td>
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<td>50 $Gy$</td>
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### Objectives

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<th>Volume</th>
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<tbody>
<tr>
<td>1</td>
<td>Cervix-uterus (CTV) (74 $Gy$)</td>
<td>minimize LTCP</td>
</tr>
<tr>
<td>2</td>
<td>Rectum</td>
<td>minimize mean</td>
</tr>
<tr>
<td>3</td>
<td>Bladder</td>
<td>minimize mean</td>
</tr>
<tr>
<td>4</td>
<td>Unspecified Tissue</td>
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Wish-list: cervix-uterus boost

List for complicated sites much longer many optimizations

How to avoid iterative optimizations while maintaining benefits of this method?
Novel Fast online method

- use **Lagrange multipliers** from Full automated multi-criteria optimization
- use weighted-sum method to optimise all objectives at once

\[ w_1 f_1(x) + w_2 f_2(x) + \ldots + w_n f_n(x) \]

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Properties

- Fast method uses only 1 optimization where the Full method uses many.
- On the same CT, both methods give identical result.
- Fast method is robust to small changes.
- On a different CT, the Fast method returns a similar plan compared to the Full method.
PERFECT FOR ONLINE ADAPTIVE PLANNING

- On a different CT, the Fast method returns a similar plan compared to the Full method.
Optimization

- Optimizations done in **YARTOS** (Yet Another Radiation Therapy Optimization Suite), in-house developed.
- Based on **interior-point** method.
- Multi-threaded *(modern 8-core server)*.
- Single, multi-criteria, beam angle optimization, non-rigid transformation, etc.
- No leaf-sequencing → dose attainable by clinical TPS.
Results

3 strategies:
- Best plan of the day
- Additional planning
- Today's PTV

3 sites:
- Cervix-uterus boost (2)
- Prostate (10)
- Liver (2)

Full method is used as golden reference!
Strategy 1: Best plan approach

- **Best-plan-of-the-day**: make a best plan regardless of previous fractions
Strategy 2: Additional plan approach

• *Additional plan*: take dose of *previous* fractions into account
Strategy 3: Today's PTV

- **PTV**: make a single PTV plan and apply every fraction (marker based translations)
Cervix-uterus: Best plan of the day
Fast vs. Full

Planning done on full bladder (234 cc)

Empty bladder (31 cc)  Intermediary bladder (78 cc)

Full: 53 seconds
Fast: 11 seconds
Cervix-uterus: Additional planning vs. Best plan

Planning done on full bladder (234 cc)

Empty bladder (31 cc)  Intermediary bladder (78 cc)
Cervix-uterus: Today vs. Adaptive

Planning done on full bladder (234 cc), and on PTV

Empty bladder (31 cc)  Intermediary bladder (78 cc)
Prostate: Best plan of the day
Fast vs. Full

- Full: 72 seconds
- Fast: 13 seconds
Prostate: Additional planning vs. Best plan
Prostate: Today vs. Adaptive
Liver: Best plan of the day
Fast vs. Full

Full: 363 seconds
Fast: 51 seconds
Conclusions

The Fast method is a valid online alternative to a Full automated optimization.

For cervix-uterus and prostate cases, we have not detected an advantage for online non-rigid transformation of dose.

Adaptive treatment planning:

• gives expected target coverage
• reduces dose to OAR