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A deep learning-enhanced auto-contouring workflow for daily-adaptive MR-guided prostate radiotherapy

- Clinical implementation and evaluation -

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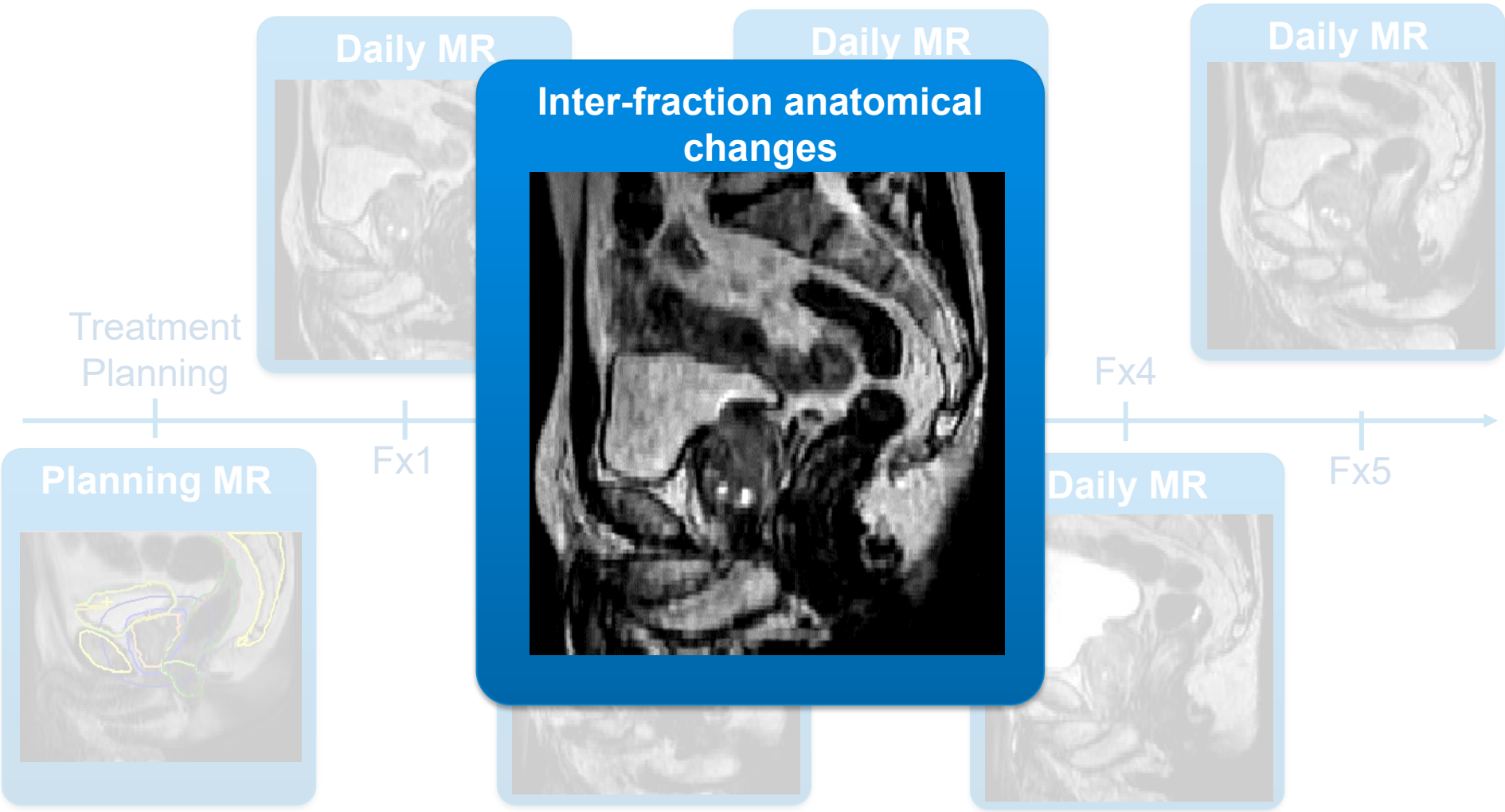
Summary of 5x7.25 Gy MRg-adaptive workflow

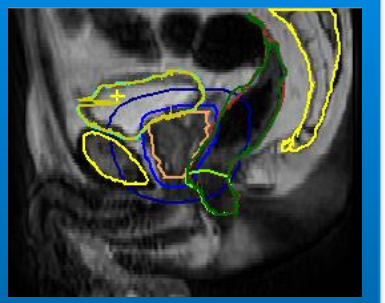


Summary of 5x7.25 Gy MRg-adaptive workflow

Track anatomical changes and make daily plan adaptions

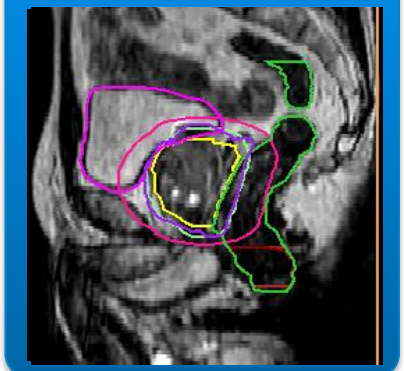
Treatment Planning

Planning MR



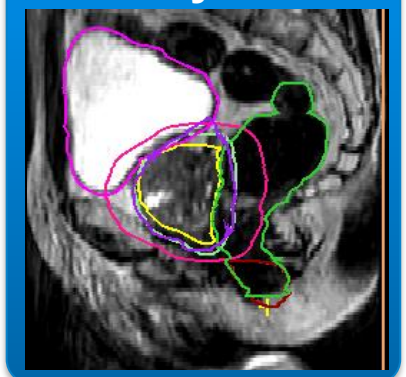
Fx1

Daily MR



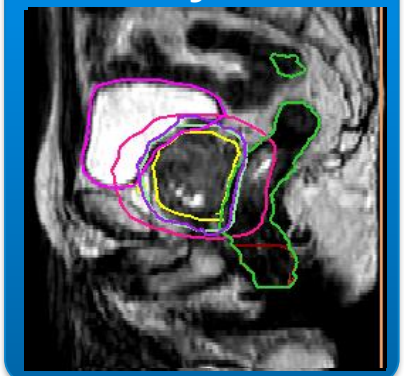
Fx2

Daily MR



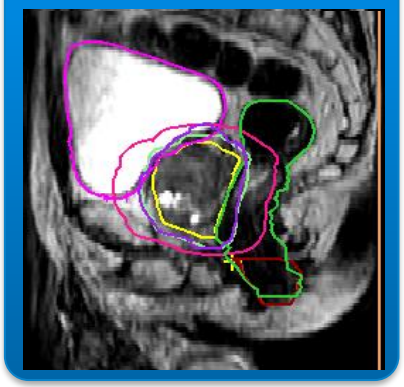
Fx3

Daily MR



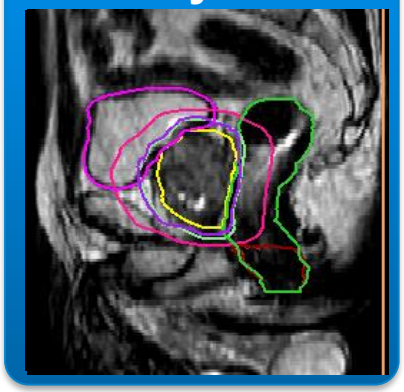
Fx4

Daily MR



Fx5

Daily MR



Former clinical solution

Daily

Former

Contour approval
within 8 – 10 mins

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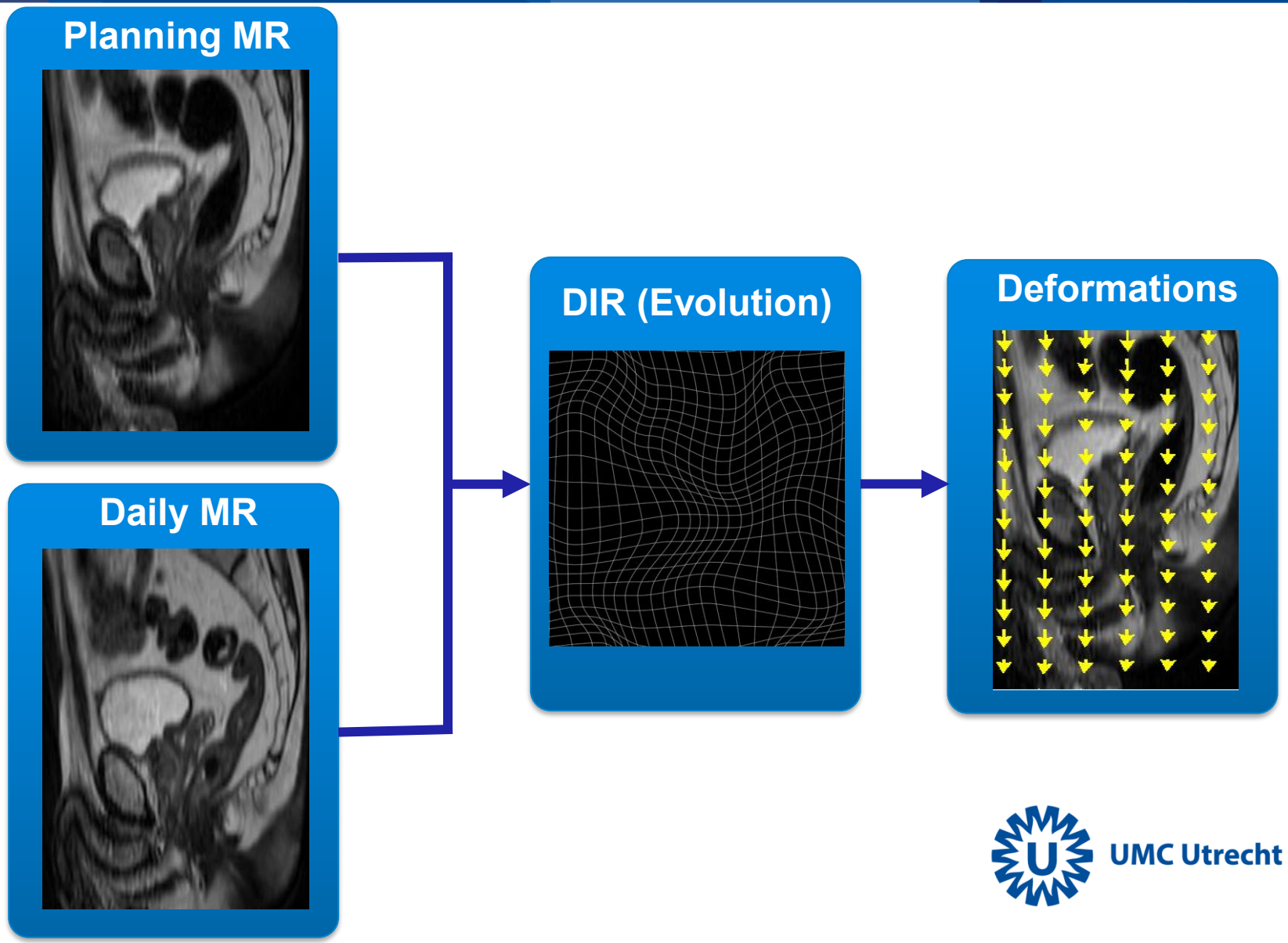
Deformable Image Registration



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Evolution pre-clinical results

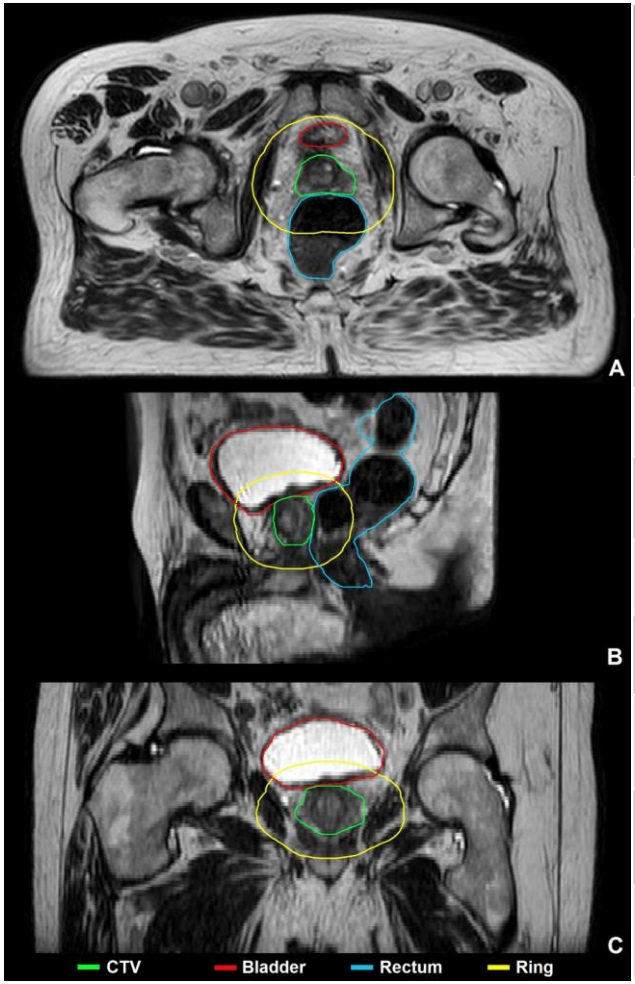


Table 1 Need for adaptations of propagated contours, stratified by 'Short' and 'Long' interval between MRI scans. Adaptions needed	Number of fractions (%)		
PV1 → PV2 (n=10)	CTV	Bladder	Rectum
None	8 (80)	10 (100)	4 (40)
Few minor	2 (20)	0 (0)	5 (50)
Multiple minor/few major	0 (0)	0 (0)	1 (10)
Multiple major	0 (0)	0 (0)	0 (0)
Pre T2 → PV1 (n=50)			
None	28 (56)	30 (60)	13 (26)
Few minor	21 (42)	18 (34)	24 (48)
Multiple minor/few major	1 (2)	1 (3)	8 (16)
Multiple major	0 (0)	1 (3)	5 (10)

*In all cases all manual adaptions were possible within **3 minutes***

Courtesy of Thomas Willigenburg

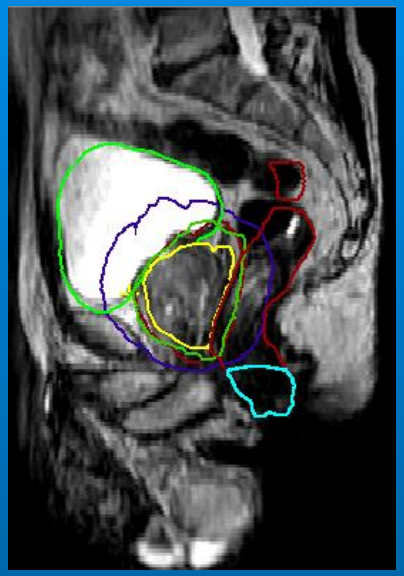
Existing (former) clinical solution

Daily

Former

Contour approval within 8 – 10 mins

Evolution



Contour approval within 6 – 8 mins

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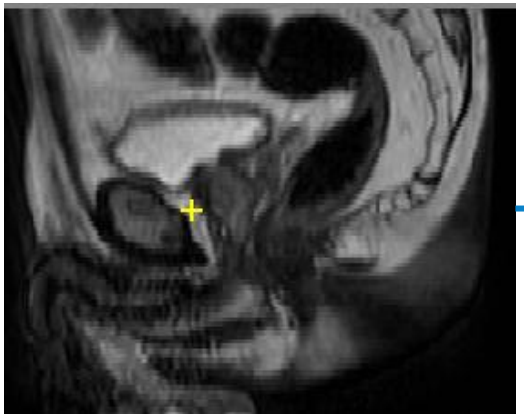
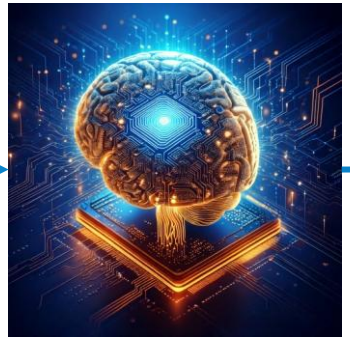
The DL-enhanced Evolution DIR algorithm

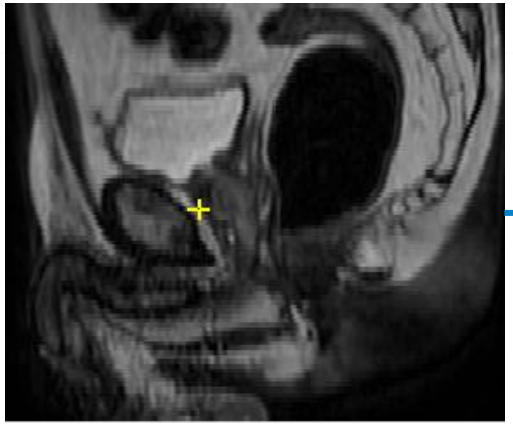
Planning MR



nnUNet

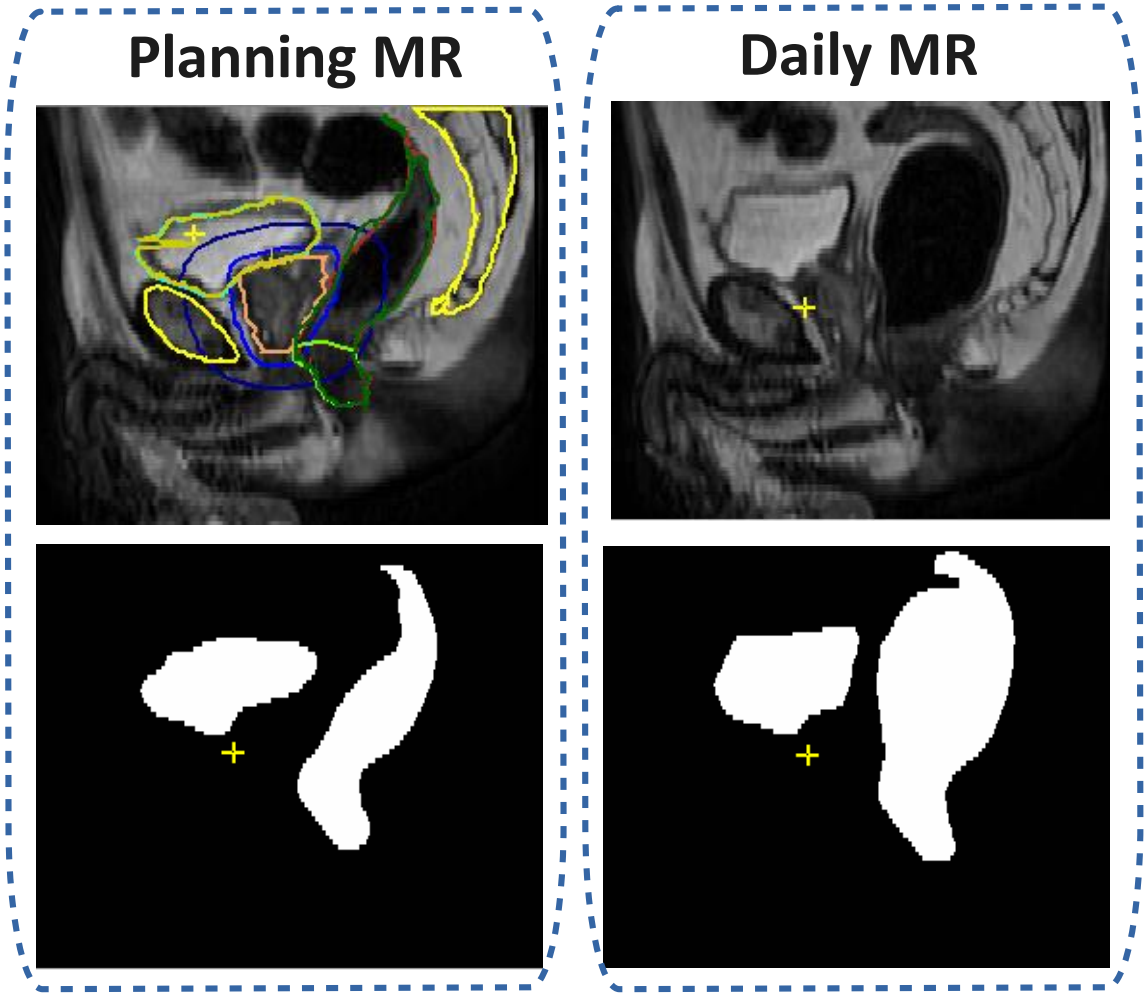


Daily MR



nnUNet

The DL-enhanced Evolution algorithm



Deformable image registration

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DL-enhanced Evolution pre-clinical results

Adaptations needed?	CTV	Within ring only Bladder	Within ring only Rectum
No adaptations needed (0)	70	91	101
Few minor adaptations needed (1)	31	12	2
Multiple minor/few major adaptations needed (2)	4	0	2
Multiple major adaptations needed (3)	0	2	0
Total where any adaptation is needed	35	14	4
Percentage where any adaptation is needed	**33%**	**13%**	**4%**
Percentage where NO adaptation is needed	**67%**	**87%**	**96%**
Percentage where multiple minor/major adaptation is needed	4%	2%	2%
Number where in none of the structures adaptations are needed	64	61%	
Number where in none of the structures adaptations are needed or only few minor	99	94%	
Total	105	105	105

*In all cases all manual adaptions were possible within **2 minutes***

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DL-enhanced Evolution – Clinical Translation

- **Online Monaco: no support for importing 3rd party structures**
- **Via offline Monaco:**
  - Initially too slow and cumbersome
  - Since Monaco v6.2.1
    - Faster and simpler

- **Implementation project: June - Nov 2024**
  - Software QMS:
    - EVolution
    - nnU-Net
  - Clinical workflow on MRL

**Courtesy of Gijs Bol*

DL-enhanced Evolution – Clinical Evaluation

- **In clinical use since 18 Nov 2024**
  - >200 patients, <1000fr

Structure	Min.	5th Qu.	25th Qu.	Median	75th Qu.	95th Qu.	Max
bladder	0.09	0.91	0.98	0.98	0.99	0.99	1.00
bladder_ring	0.02	0.82	0.97	0.98	0.99	0.99	1.00
rectum_ring	0.54	0.93	0.97	0.97	0.98	0.98	1.00
rectum	0.63	0.95	0.97	0.98	0.98	0.99	1.00
femur_l	0.83	0.98	0.98	0.98	0.98	0.98	1.00
femur_r	0.80	0.98	0.98	0.98	0.98	0.98	1.00
gtv	0.00	0.66	0.85	0.89	0.92	0.95	1.00
bony_structures	0.76	0.97	0.98	0.98	0.98	0.98	1.00
ctv	0.42	0.91	0.96	0.96	0.97	0.98	0.99
prostate	0.82	0.91	0.95	0.97	0.98	0.98	0.99

Dice Similarity Coefficient

Structure	Min.	5th Qu.	25th Qu.	Median	75th Qu.	95th Qu.	Max
bladder	0.00	0.70	0.70	0.70	0.99	5.20	24.77
bladder_ring	0.00	0.35	0.70	0.70	1.49	5.72	23.55
rectum_ring	0.35	0.70	0.70	0.70	0.70	3.00	18.82
rectum	0.00	0.70	0.70	0.70	0.70	2.29	22.31
femur_l	0.62	0.70	0.70	0.70	0.70	0.99	8.00
femur_r	0.00	0.70	0.70	0.70	0.70	0.70	7.98
gtv	0.00	0.70	0.70	0.70	0.99	0.99	19.66
bony_structures	0.00	0.70	0.70	0.70	0.70	0.70	6.64
ctv	0.70	0.70	1.32	2.00	2.06	5.56	24.22
prostate	0.62	0.70	0.70	0.70	2.00	4.20	7.88

95% Hausdorff Distance

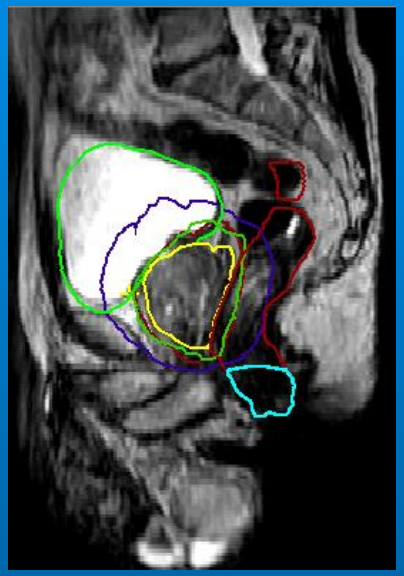
DL-enhanced Evolution – Clinical Translation

Daily

Former

Contour approval within 8 – 12 mins

Evolution



Contour approval within 6 – 8 mins

DL + Evolution

Contour approval within 3 – 4 mins

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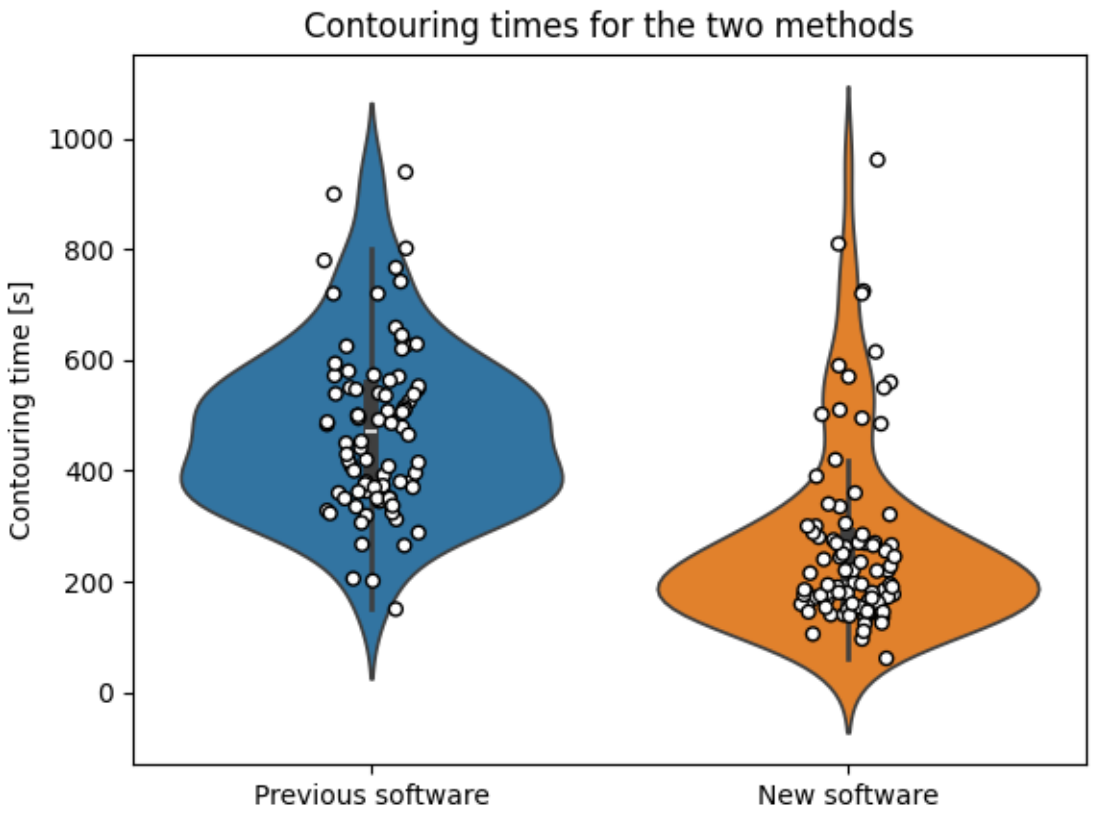
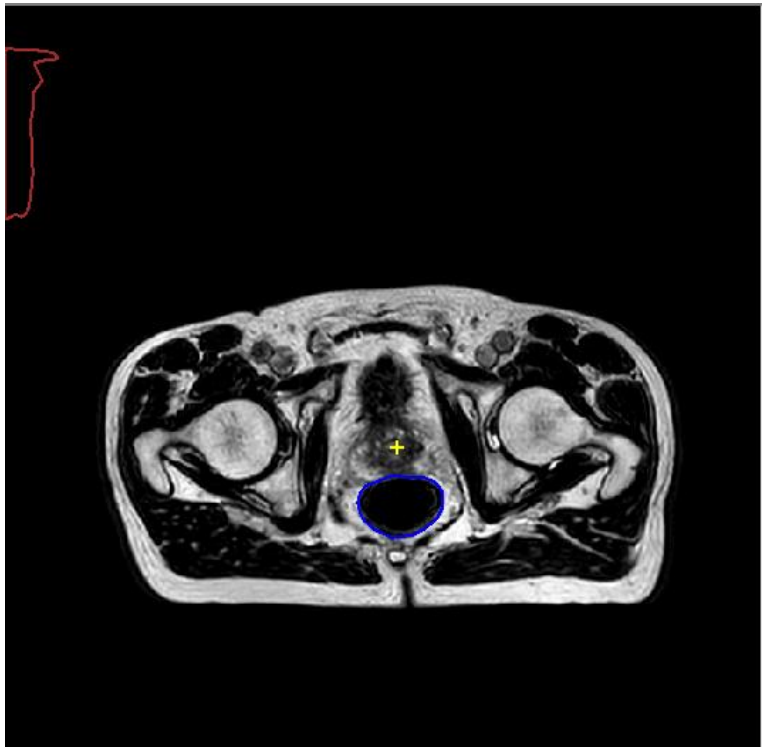
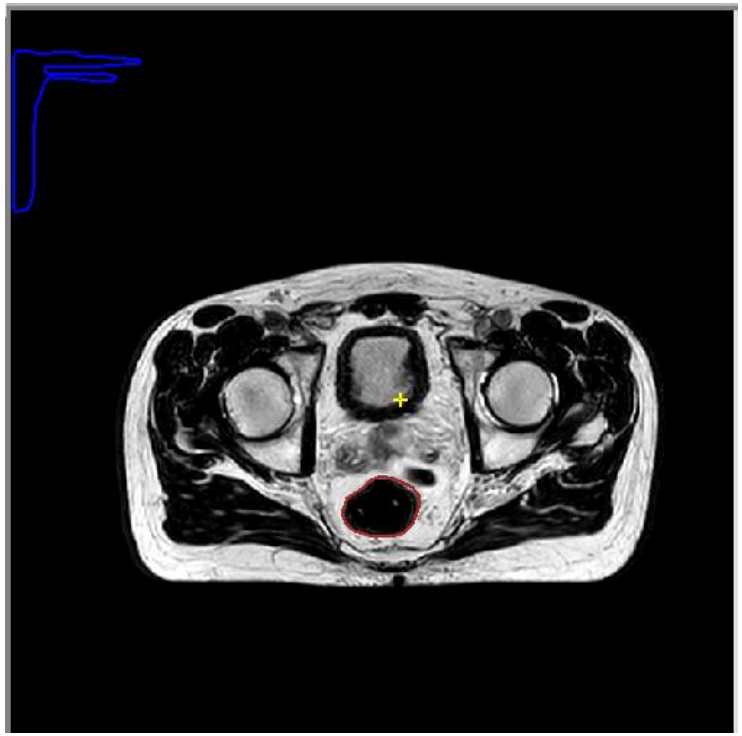
DL-enhanced Evolution – Clinical Evaluation



DL-enhanced Evolution – Clinical Evaluation

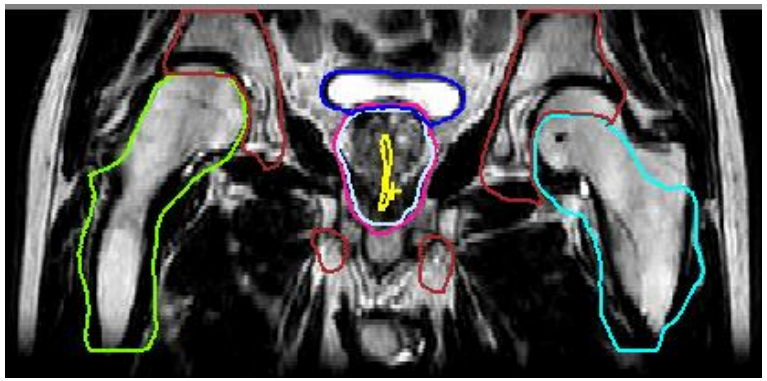
- **Issue with guiding contour generation**

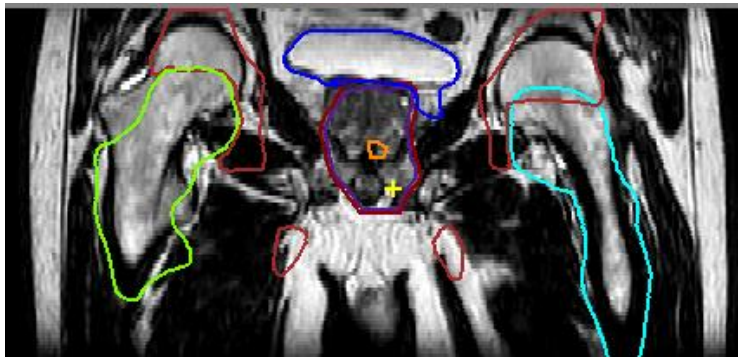




DL-enhanced Evolution – Clinical Evaluation

- **Issue with registration**





Wrap-up and Outlook

- **In clinical use since 18 Nov 2024**
  - >200 patients, <1000fr
  - Timing: 90 seconds
- **Applied on all MRL ATS prostate patients**
  - Timeslot to 30 – 35 min
- **Extension to other treatment sites:**
  - Rectum
  - Cervix
  - Esophagus
  - Etc…

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Acknowledgments

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A deep learning-enhanced auto-contouring workflow for daily-adaptive MR-guided prostate radiotherapy

- Clinical implementation and evaluation -

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