GPU-Accelerated auto-segmentation for adaptive radiotherapy

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NCAAPM Spring Meeting 2010
Madison, WI

Froedtert & Medical College of Wisconsin

Overview

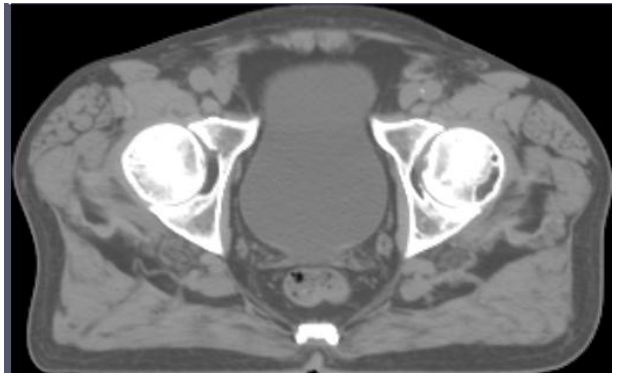
- Motivation
  - Adaptive Radiation Therapy
  - Auto Segmentation
  - GPU
- Implementation and evaluation
- Results
- Further development and applications

Adaptive Radiation Therapy

- Inter-fractional variations
  - Prostate & Prone Breast
- Rigid translation not enough
  - Ignores size and shape changes
- Imaging capabilities (in room kV) not fully used
- Full re-planning not yet practical
- Need fast, online adaptive planning

Plan

Daily



MCW Online Adaptive Workflow

Image Acquisition via in-room CT

↓

Contour generation (modified from the original contours) 5+ min

↓

Adaptive Planning & DVH 3 min

↓

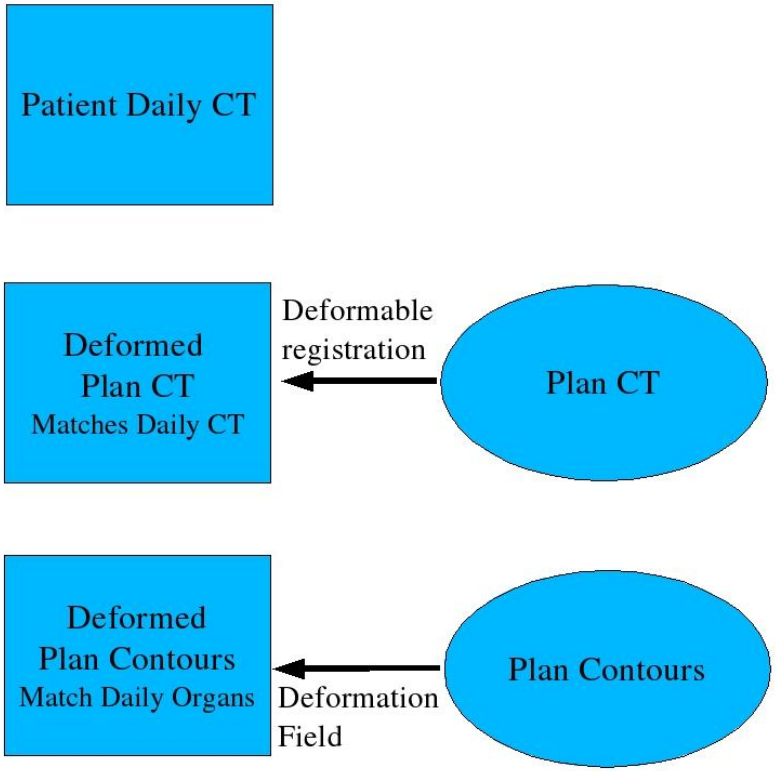
New MLC transferred for treatment 1 min

Comparable to IGRT ~ 5 - 10 min

⇨Need contours each day

Ahunbay EE *et al,* An on-line replanning scheme for interfractional variations, *Med Phys* 2008;35: 3607-3615.

Auto-Segmentation



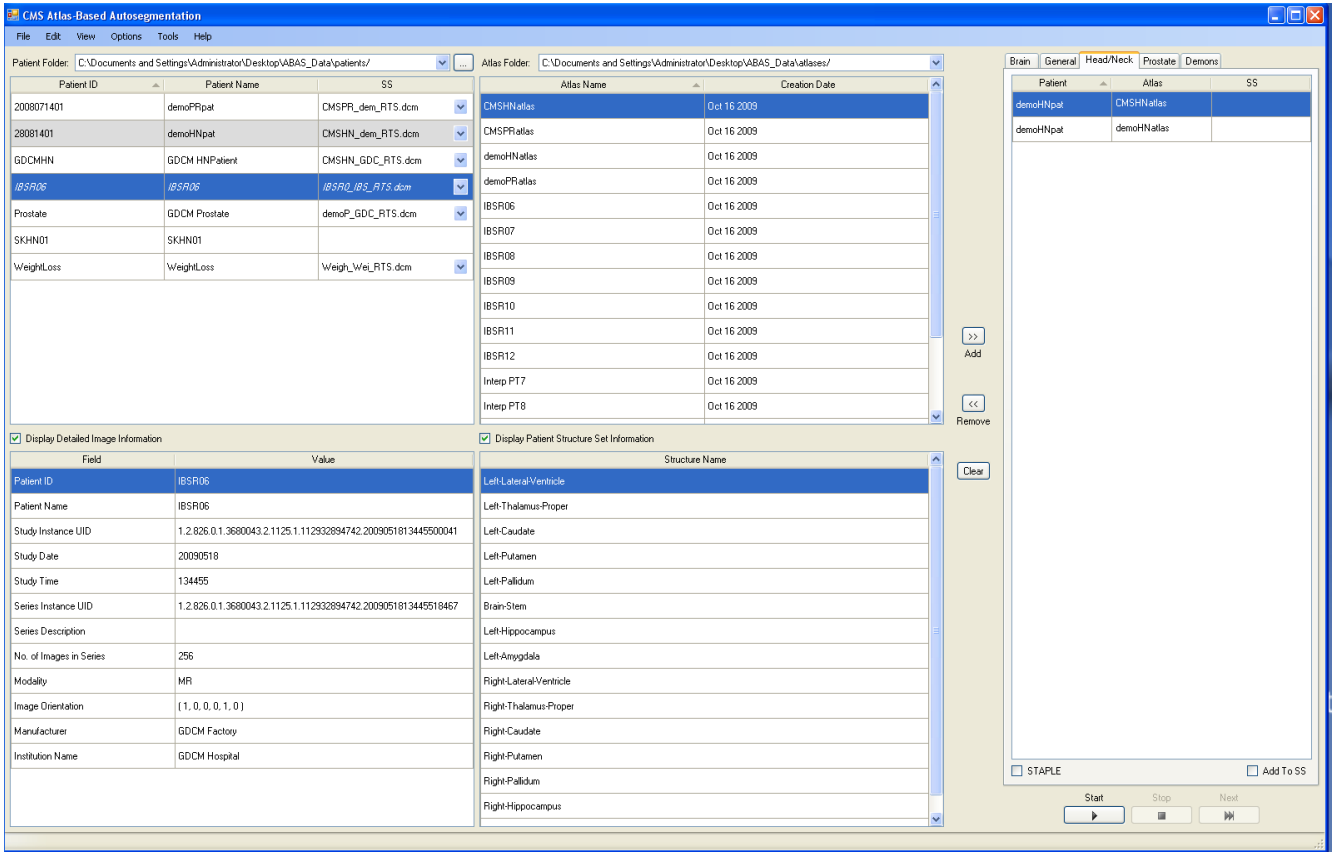
- Deform plan CT to daily CT
- Determined deformation field deforms plan contours to the anatomy of the daily CT
- Quick, accurate and consistent

Graphics Processor Unit

- Inexpensive parallel computing
- NVidia Compute Uniform Device Architecture (CUDA)
  - Also OpenCL
- Single instruction multiple data (Kernels):
  - Gradient Calculation
  - Smoothing
  - Deformation
  - Interpolation
  - Comparison

ABAS, CMS Inc

- CPU or GPU
- Only deformable registration runs on GPU
  - Limits speed increase
- 64 bit OS preferred (memory)

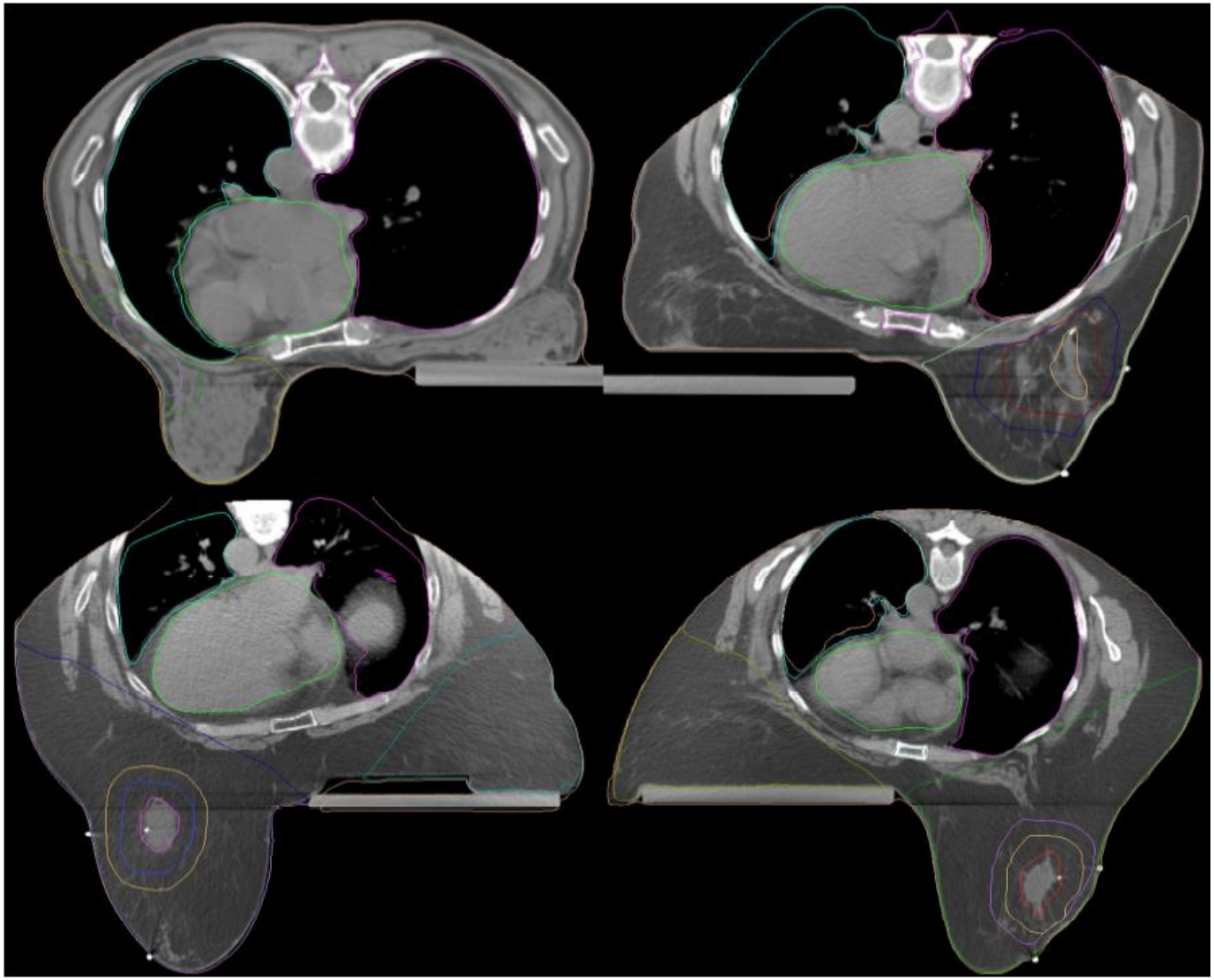


Evaluation

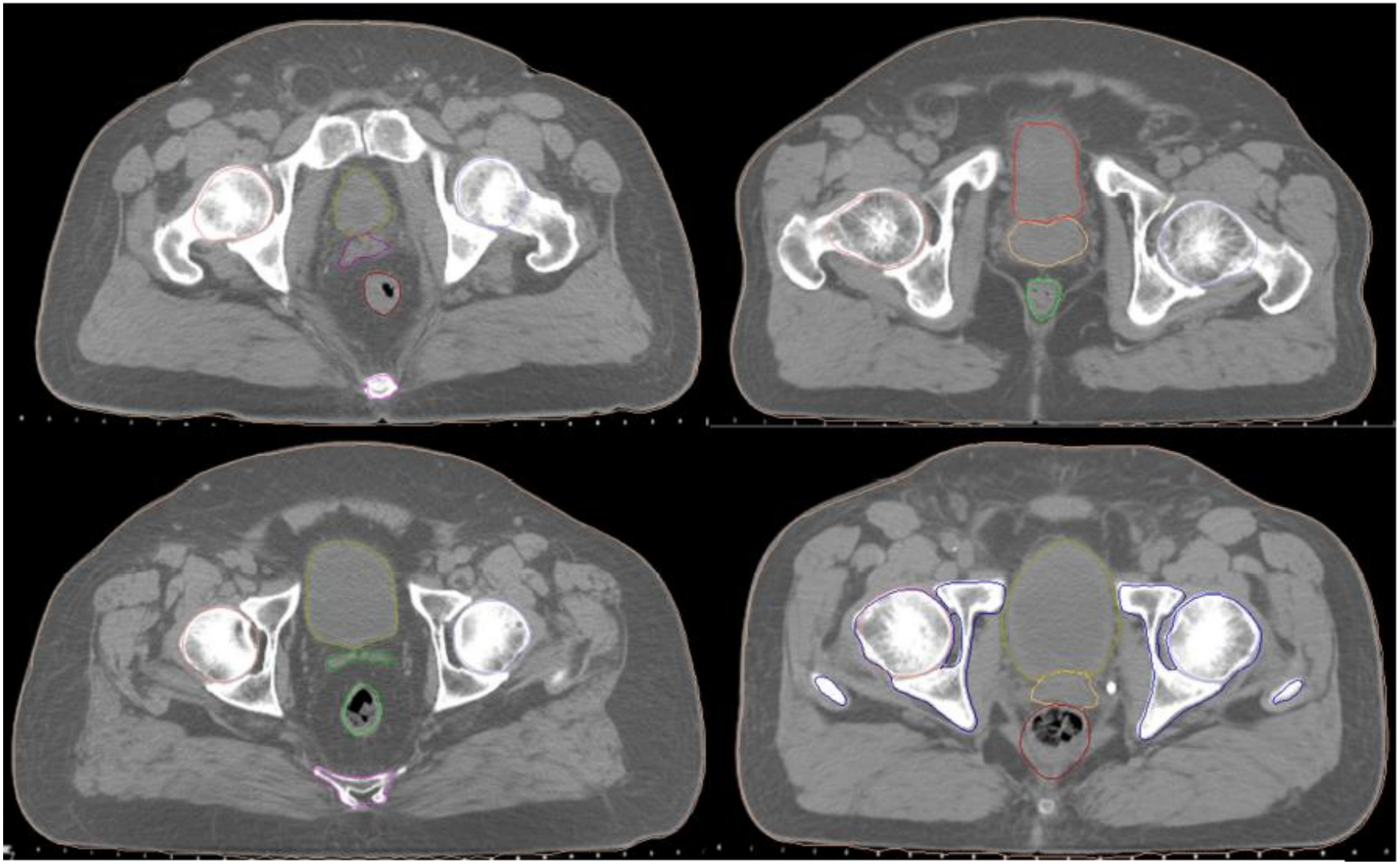
- 6 prostate patients (2 fractions each)
  - Treated with IGRT, IMRT, ART
- 4 prone breast patients (all 10 fractions)
  - Boost field with IGRT, IMRT

- GPU: 240 core NVidia GTX 285
- CPU: two Intel Xeon four core, 3 GHz, 3.25 GB memory, WinXP 32bit

Results: Prone Breast



Results: Prostate



Results: Speed and Accuracy

- Accuracy: Dice's coefficient between physician and auto-segmented contours
  - overlap volume divided by average volume
- Average of all fractions:

		Bladder	Rectum	Prostate	Time(min)
GPU	Average	92.4	**86.6**	85.8	**1.4**
CPU	Average	**92.6**	85.5	**86.3**	1.9

- Speed depends on # slices in daily CT
  - 56 slices – under a minute

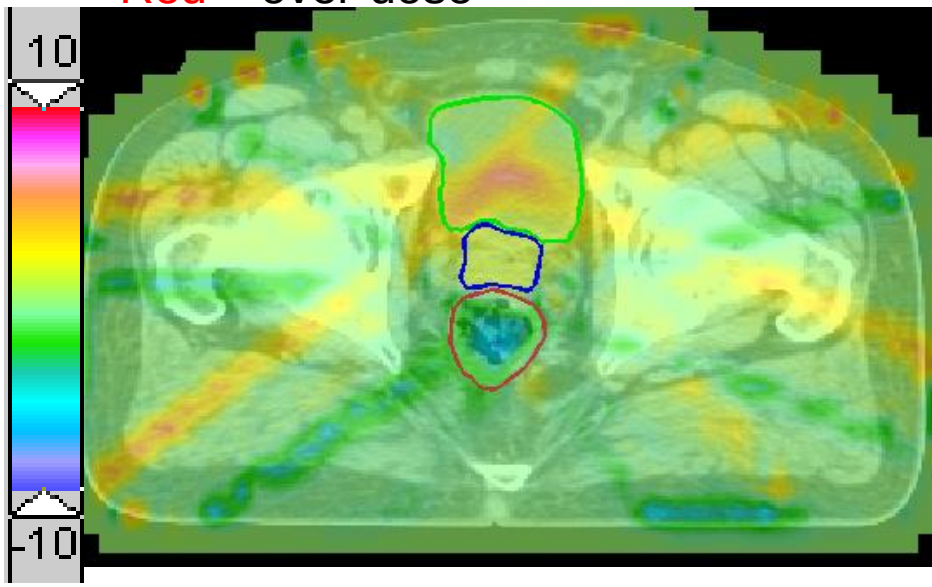
Continued…

- No physician contours on prone breast daily CTs
- Compared CPU and GPU generated
  - No difference (Dice > 95%)
- GPU average: 2.8 mins
  - Short scan (55 slices) 1.3 mins
- CPU average: 4.2 mins

Further Development

- Base adaptive plan on delivered dose
  - Need to accumulate previously delivered dose
- ABAS exports deformation field
  - Use same field for dose and contours
- Also use deformation field to morph beam apertures
- GPU dose calculation

Difference in plan versus delivered:
Blue – under-dose
Red – over-dose



Atlas Based Segmentation

- Original design of ABAS – use ATLAS, generic patient(s)
- At MCW using for:
  - Supine breast (based on RTOG guidelines)
  - Head and Neck
  - Prostate
- Reduces physician contouring time and more consistent contours
- Rescans
- Research

Supine Breast

- Investigated ATLAS to plan CT for 30 supine breast patients
- Average DC between 10 physicians (inter observer accuracy):
  - right breast 89 ± 2%
  - left chest wall 86 ± 4%
  - left breast 93 ± 4%
  - heart 90 ± 5%
- Average DC between the generated and physician drawn:
  - right breast 90 ± 5%
  - left chest wall 86 ± 3%
  - left breast contours 87 ± 2%
  - heart 87 ± 6%
- All generated contours reviewed by the attending physician and found clinically acceptable
- CPU: 4.4 mins GPU: 2.3 mins, equivalent accuracy

Conclusion

- GPU auto-segmentation gives accurate contours in ~ 1 minute
  - ⇨ Online ART feasible

Acknowledgements

- Colleen Lawton MD
- Dian Wang MD PhD
- Julia White MD
- Siemens
- CMS/Elekta