



GPU-Accelerated auto-segmentation for adaptive radiotherapy

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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

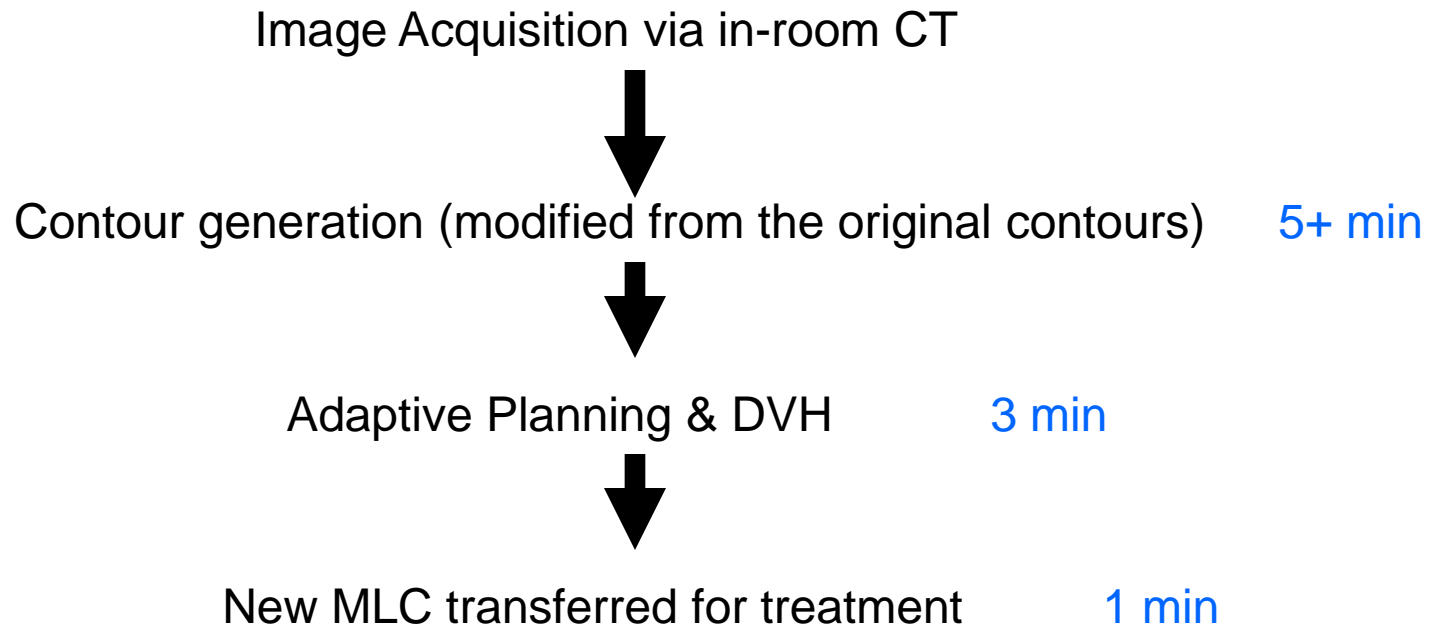
Plan



Daily



MCW Online Adaptive Workflow

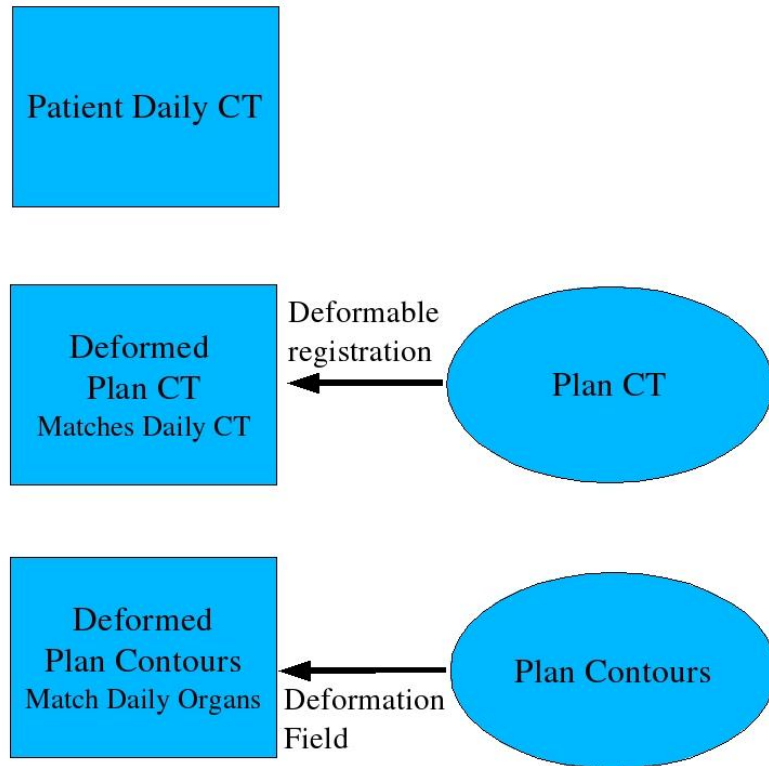


Comparable to IGRT ~ 5 - 10 min

⇒ 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)

Patient Folder: C:\Documents and Settings\Administrator\Desktop\ABAS_Data\patients/

Patient ID	Patient Name	SS
2008071401	demoPRpat	CMSPP_dem_RTS.dcm
28081401	demoHNpat	CMSHN_dem_RTS.dcm
GDCMHN	GDCM HNPatient	CMSHN_GDC_RTS.dcm
IBSR06	IBSR06	IBSR0_IBS_RTS.dcm
Prostate	GDCM Prostate	demoP_GDC_RTS.dcm
SKHN01	SKHN01	
WeightLoss	WeightLoss	Weight_Wei_RTS.dcm

Atlas Folder: C:\Documents and Settings\Administrator\Desktop\ABAS_Data\atlases/

Atlas Name	Creation Date
CMSHNAtlas	Oct 16 2009
CMSPPAtlas	Oct 16 2009
demoHNAtlas	Oct 16 2009
demoPRAtlas	Oct 16 2009
IBSR06	Oct 16 2009
IBSR07	Oct 16 2009
IBSR08	Oct 16 2009
IBSR09	Oct 16 2009
IBSR10	Oct 16 2009
IBSR11	Oct 16 2009
IBSR12	Oct 16 2009
Interp_PT7	Oct 16 2009
Interp_PT8	Oct 16 2009

Display Detailed Image Information

Field	Value
Patient ID	IBSR06
Patient Name	IBSR06
Study Instance UID	1.2.826.0.1.3680043.2.1125.1.112932894742.2009051813445500041
Study Date	20090518
Study Time	134455
Series Instance UID	1.2.826.0.1.3680043.2.1125.1.112932894742.2009051813445518467
Series Description	
No. of Images in Series	256
Modality	MR
Image Orientation	(1, 0, 0, 1, 0)
Manufacturer	GDCM Factory
Institution Name	GDCM Hospital

Display Patient Structure Set Information

Structure Name
Left-Lateral-Ventricle
Left-Thalamus-Proper
Left-Caudate
Left-Putamen
Left-Pallidum
Brain-Stem
Left-Hippocampus
Left-Amygdala
Right-Lateral-Ventricle
Right-Thalamus-Proper
Right-Caudate
Right-Putamen
Right-Pallidum
Right-Hippocampus

Brain | General | Head/Neck | Prostate | Demons

Patient	Atlas	SS
demoHNpat	CMSHNAtlas	
demoHNpat	demoHNAtlas	

STAPLE Add To SS

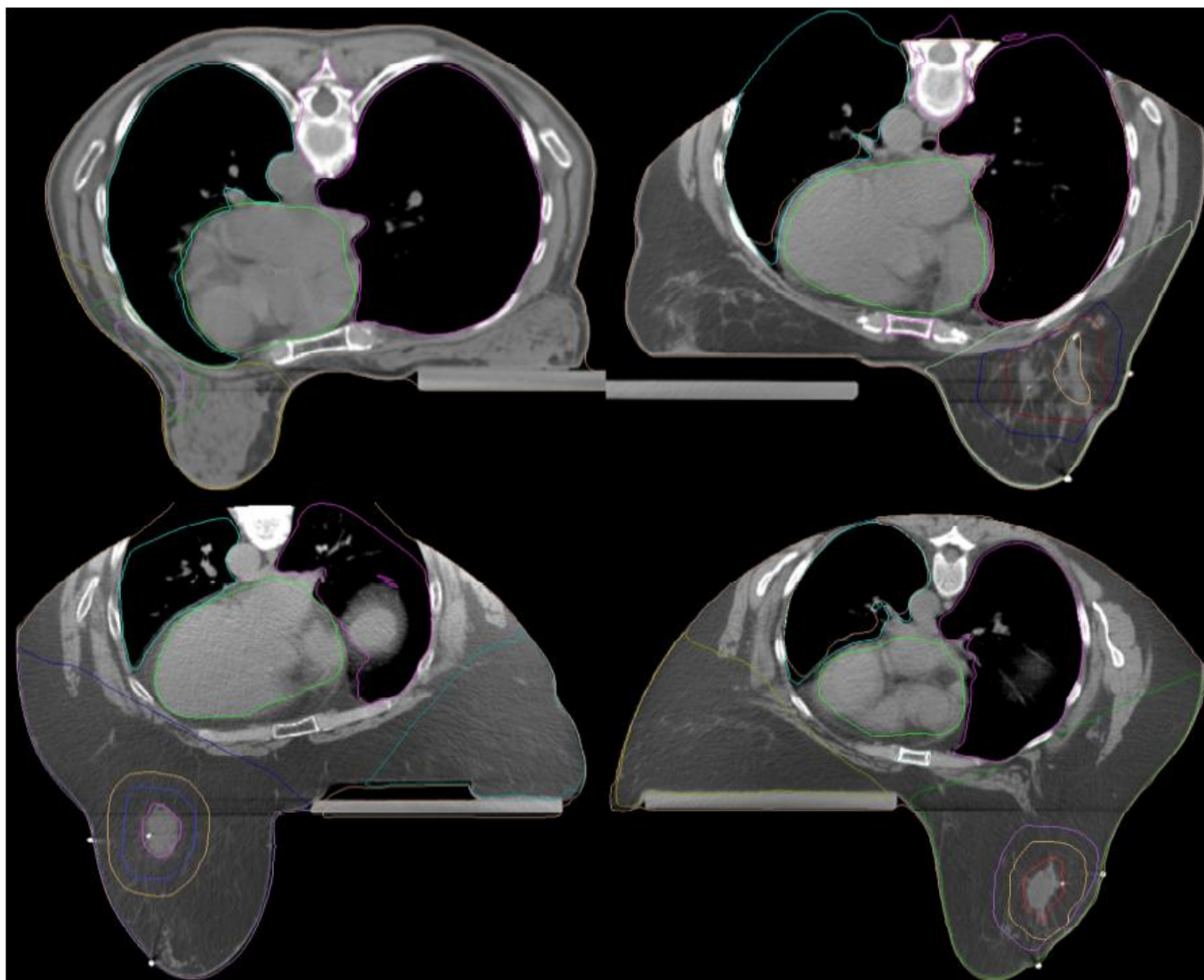
Start Stop Next

Evaluation

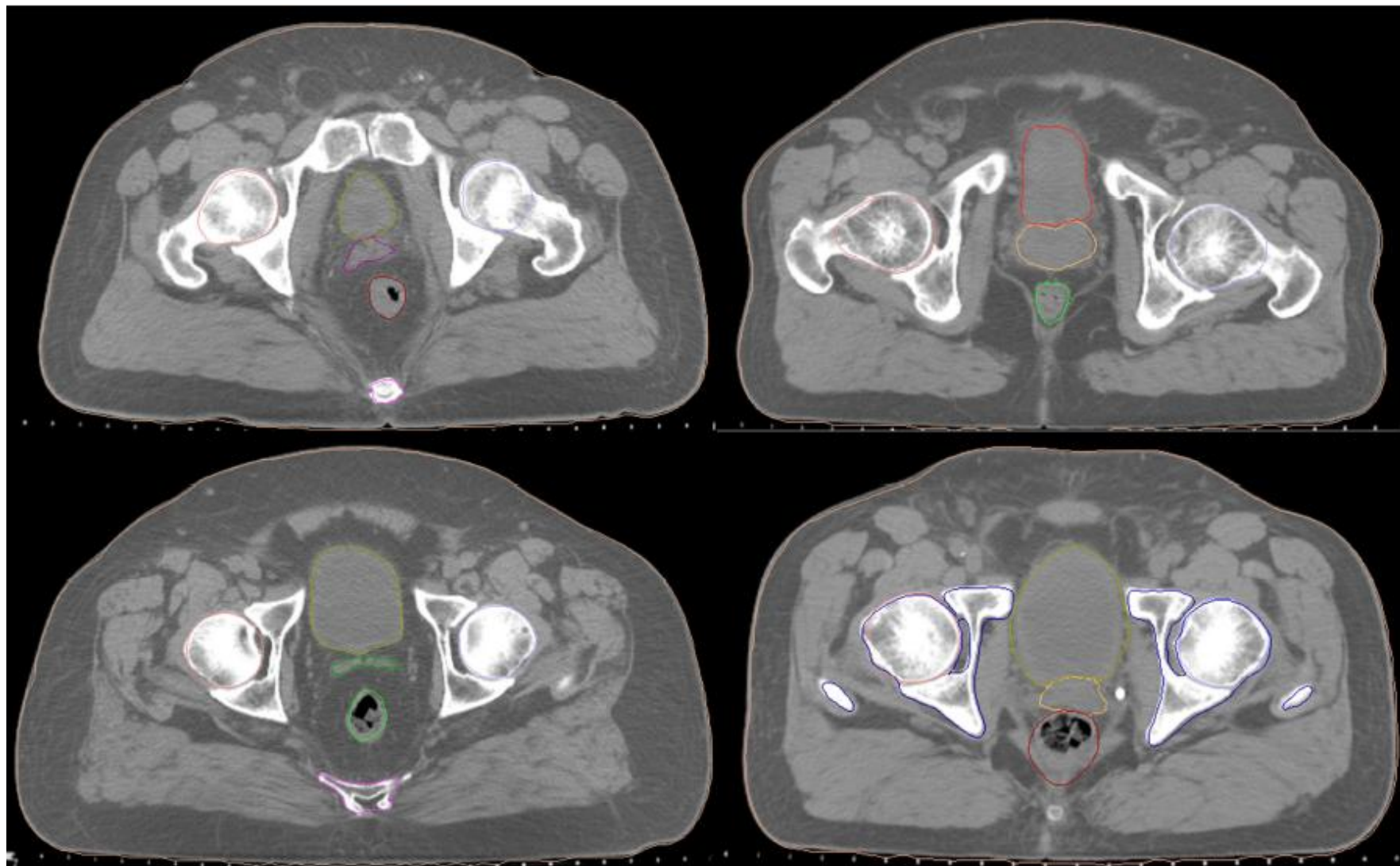
- 6 prostate patients (2 fractions each)
 - Treated with IGRT, IMRT, ART
- 4 prone breast patients (all 10 fractions)
 - Boost field with IGRT, IMRT

- 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

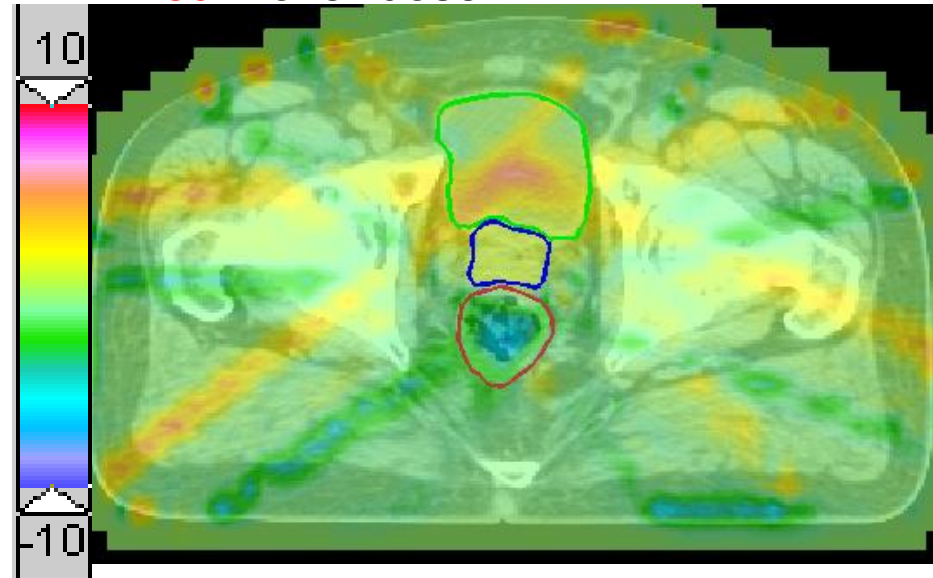
Further Development

- 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 $89 \pm 2\%$
 - left chest wall $86 \pm 4\%$
 - left breast $93 \pm 4\%$
 - heart $90 \pm 5\%$
- Average DC between the generated and physician drawn:
 - right breast $90 \pm 5\%$
 - left chest wall $86 \pm 3\%$
 - left breast contours $87 \pm 2\%$
 - heart $87 \pm 6\%$
- **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
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