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
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

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:

<table>
<thead>
<tr>
<th></th>
<th>Bladder</th>
<th>Rectum</th>
<th>Prostate</th>
<th>Time(min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU Average</td>
<td>92.4</td>
<td>86.6</td>
<td>85.8</td>
<td>1.4</td>
</tr>
<tr>
<td>CPU Average</td>
<td>92.6</td>
<td>85.5</td>
<td>86.3</td>
<td>1.9</td>
</tr>
</tbody>
</table>

- 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

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