Using Atlas Information to Improve Cancer Treatment

Edinburgh Cancer Centre

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15 May 2012
Overview

- Introduction to Radiotherapy
  - The radiotherapy journey
  - Radiotherapy delivery
- Identifying Organs and Planning
  - CT scanning
  - Treatment planning
- Using Atlas Information to Improve Treatment
  - For automatic segmentation and contouring
  - Real-time, adaptive, radiotherapy planning
  - Outcome-driven radiotherapy
The Radiotherapy Journey

- Imaging
- Treatment Planning
- Verification
- Treatment
CT Imaging
Treatment Planning

Imaging → Planning → Verification → Treatment
Treatment Planning
Image Verification
Image Verification and Treatment
Using an Atlas for Segmentation

- 11 radiation oncologists from 5 difference centres
- GTV on CT for 22 patients
- Large observer variation
- Considerable variation in style

Using an Atlas for Segmentation

Table 1
For all radiation oncologists, the mean GTV volume, the mean distance (measured from the median surface to each individual GTV), overall observer variation (overall SD), mean delineation time, mean number of slice changes, mean number of delineated points and mean number of corrections

<table>
<thead>
<tr>
<th>Radiation oncologist</th>
<th>Mean volume (cm³)</th>
<th>Mean distance (cm)</th>
<th>Overall SD (cm)</th>
<th>Mean time (min)</th>
<th>Mean no. slice changes</th>
<th>Mean no. delineated points</th>
<th>Mean no. corrections</th>
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<tr>
<td>1</td>
<td>36</td>
<td>−0.64</td>
<td>1.51</td>
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<td>288</td>
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<td>1.39</td>
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<td>−0.16</td>
<td>1.00</td>
<td>27</td>
<td>143</td>
<td>225</td>
<td>53</td>
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<tr>
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<td>0.62</td>
<td>15</td>
<td>121</td>
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<td>49</td>
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<td>0.66</td>
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<td>18</td>
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<td>0.61</td>
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<td>238</td>
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<tr>
<td>All</td>
<td>69 (25)</td>
<td>−0.17</td>
<td>1.02</td>
<td>16</td>
<td>185</td>
<td>225</td>
<td>39</td>
</tr>
</tbody>
</table>

Radiation oncologists are ranked according to increasing mean delineated volume. SD, standard deviation. The number in the parenthesis is the standard deviation of the mean volumes of the observers.

Using an Atlas for Segmentation

Left, CT slice through a prostate and (right) the corresponding MR scan. Khoo and Joon 2006.
Image Analysis for Segmentation
Image Analysis for Segmentation

Another feature $F_3$ corresponding to PC 3 can just be the sum of Feature 3:

$$F_2 = \sum_{i=1}^{d} (F_3(d = i))$$

Figure 4.9

The $F_1$ and $F_2$ are scattered in Figure 4-9. The red dots stand for the features from ROIs within GTV while the blue dots stand for the features from ROIs of non-GTV. $F_1$ represents the difference of two homogeneity measurements. From the scatter plot it can be seen as $d$ varied the GTVs had the difference of two entropies represented by $F_1$ much smaller than the non-GTVs, which implies that statistically the GTVs are more homogeneous than non-GTVs. $F_3$ alone show limited separation power; however it assists the $F_1$. For understanding the distribution of the features, the conditional probability, or likelihood function can be estimated:

$$p(F_1, F_2 | T_i) \sim N(\mu_i, \Sigma_i)$$

where $N(\mu_i, \Sigma_i)$ is the two dimensional Gaussian distribution with mean vector $\mu_i$ and covariance $\Sigma_i$. 

$$X \times 10^4$$
Automatic Contouring

Automatic Contouring

Qualitative Evaluation

Excellent
Good
Acceptable
Not Acceptable

Random Case Selection
4 excellent, 3 good, 1 acceptable

Using an Atlas for Adaptive RT

Improving the Accuracy of Radiotherapy Using Information from an Atlas

Radiotherapy Planning CT Scan → Radiotherapy Plan

Time-of-Treatment Imaging (CBCT) / (PET?)

NO Re-planning → Shift patient
Using an Atlas for Adaptive RT
Using an Atlas for Adaptive RT

Improving the Accuracy of Radiotherapy Using Information from an Atlas

- Radiotherapy Planning CT Scan
- Radiotherapy Plan
- Time-of-Treatment Imaging (CBCT) / (PET?)
- Select best match for image and plan
- Atlas - Anatomical/planning information
An Atlas for Outcome-driven RT
An Atlas for Outcome-driven RT

Fig. 3. (a) Consolidation, (b) nodules and nodular structures, (c) ground glass nodular opacities.
An Atlas for Outcome-driven RT

- Pre and post-RT Patient Information
  - Smoking status
  - Co-morbidities
  - Drugs
  - Pathology
  - Stage & Grade
  - Exercise tolerance
  - Pneumonitis grading (0, 1 mild, 2 moderate, 3 severe, 4 death)
  - Planning target volume (volume irradiated)
An Atlas for Outcome-driven RT
An Atlas for Outcome-driven RT

- Radiotherapy Planning CT Scan
- Radiotherapy Plan
- Atlas - Anatomical, Biological, Planning and Outcome Data
- New RT Plan from Atlas
- Atlas - Anatomical, Biological, Planning and Outcome Data
- Time-of-Treatment Imaging (CBCT) / (PET?)
Acknowledgements

- Dr Duncan McLaren
- Dr Robin Steel
- Prof Steve McLaughlin
- Hanqing Liao
- Yuan Tian
- Prof Ian Kunkler
- Prof David Cameron
- Dean Montgomery
- Yang Feng
- Kun Cheng

- Dr Sara Erridge
- Prof David Argyle