Segmentation and Tracking of ROIs for Image-Guided Fractionated Radiotherapy

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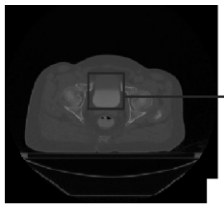
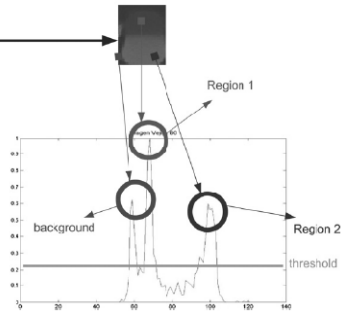
Purpose

Organ motion should be taken into account for image-guided fractionated radiotherapy. Organ modelling is of key importance to improve the conformation of the dose delivered to the target (tumoral tissues), whatever its shape, in order to spare surrounding tissues. It may be applied for several purposes including segmentation, registration and tracking. A novel method for performing deformable segmentation and tracking has been developed for inter/intra-fraction organ motion planning and evaluation.

Materials and Methods

- Energy minimizing active model were synthesized for tracking a set of organs delineated by regions of interest (ROI) in radiotherapy treatment. The initial model consists of a surface deformed to match the ROI contour by geometrical and morphological properties, following a heat flow model driven by region and boundary information. The model is based on statistical analysis of the ROI histogram.





Original Geodesic Model $E(v(s)) = \int_{\Omega} g(|\nabla I(v(s))|^2)ds + \int_{\Omega} |\dot{v}(s)|^2 \, ds$

From curve to region

and with grey level statistical analysis

$$E(\partial R) = \underbrace{(1-\alpha)\int_{\Omega} g(|\nabla I(\partial R(c))|)dc + \int_{\Omega} |\partial \dot{R}(c)|\,dc}_{\text{Contour Module}} - \underbrace{\alpha \int_{\Omega} \varphi(u)du}_{\text{Region Module}}$$

$$\varphi(u) = \sqrt{((\bar{u} \pm \sigma) - i)^2}$$

ROI histogram information

Distance Map Region 1

9	56	25
2	1	4
89	4	96
7	25	78

Distance Map Region 2

34	25	12
56	2	1
48	89	4
25	7	25

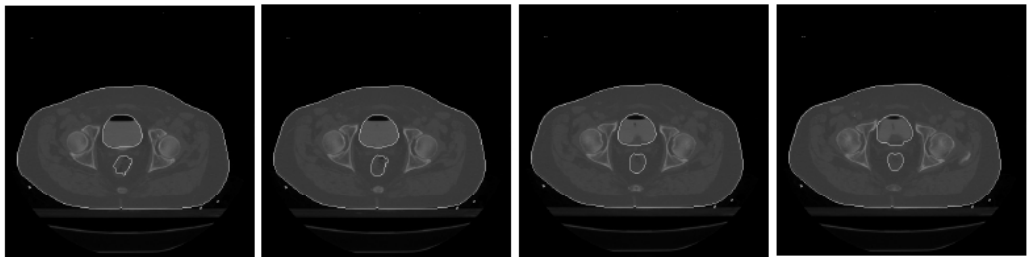
9	25	12
2	1	1
48	4	4
7	7	25

Final Distance Map

linear combination of distance maps to each target region.

Results

- In order to assess the performance of the segmentation, the results were compared against those obtained by manual segmentation, carried out with the TPS ADAC Pinnacle, and quantitative measures including sensitivity and specificity were obtained.
- Experimental evaluation of automated versus manual segmentation was done for the cardiac, thoracic and pelvic regions for real CT data. It was also tested using a Shepp-Logan head CT simulation and CT with added noise and partially occluded organs.
- The quantitative validation gave an average of 98.23% and 99.35% for the sensitivity and specificity, respectively, 92.81% for the Jaccard index, 97.55% for the Dice coefficient and 0.98%mm for the Hausdorff distance.
- The method be used for accurate segmentation in the CT, all of which results in adaptive radiotherapy. In this process, intra/inter-fraction changes in tumour shape and position can be accurately detected and tracked. Thus, the dose delivery for treatment fractions can also be adaptively modified to compensate for inaccuracies.



Results of the segmentation model applied to ROI tracking of a pelvic CT sequence.

Conclusions

- Model-based segmentation and ROI tracking was developed and tested for image-guided RTP. The method is efficient, robust and has sufficient accuracy for 2D CT data without markers.
- Using the implemented geodesic active region model to accurately track the clinical target volume, a full implementation of IGRT is possible using only the 2D.

Acknowledgements

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