Automatic Segmentation of Prostate Bed in Post-Prostatectomy CT Images

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PURPOSE

Prostate bed (or prostatic fossa) segmentation in planning CT image is essential to the clinical target volume (CTV) definition in the post-prostatectomy radiotherapy. However, due to the non-contrast boundaries and highly variable appearance, prostate bed is often referred to as "virtual volume" [1,2] or "invisible target"[3]. The segmenting of the prostate bed is a challenging task and typically carried out by the physicians using manual contouring tools, which is time-consuming and prone to inter-observer variation. In this work, we built an **atlas model** to segment the prostate bed and surrounding normal structures automatically and efficiently.

METHOD

This study is carried out in two stages.

- **Stage I: Data preparation and atlas building.**

186 post-prostatectomy cases from the year 2009 to 2019 were collected. Each case contains one planning CT image and a structure set of organs at risks (OARs) and the prostate bed. To evaluate the performance of the atlas segmentation workflow, a **five-fold cross-validation** strategy was used in this study, which is illustrated in Figure 1(a). Specifically, the collected cases were randomly divided into five folds (with the size of 37/37/37/37/38 cases, respectively). Each fold will be used as testing group (testing case) alternatively, while the rest four folds were used for building up the atlas model (atlas case).

- **Stage II: Atlas-based auto-segmentation.**

The atlas model and workflow for auto-segmentation were built with **MIM software** and is illustrated in Figure 1(b). The testing case was first compared to the atlas to find out *N* best-matched atlas cases. In this study, the hyper-parameter *N* was set to 4, which was a balanced value for performance and efficiency. Then, once the best-matched cases were found, they were registered to the testing case by deformable registration. The contours from the *N* matched atlas cases were transformed to the testing case. Finally, a majority voting operation was performed to combine the *N* transformed contours into one to create the final segmentation. The experimental results were evaluated by the dice similarity coefficient (**DSC**) and average symmetric surface distance (**ASD**) on all the cases.

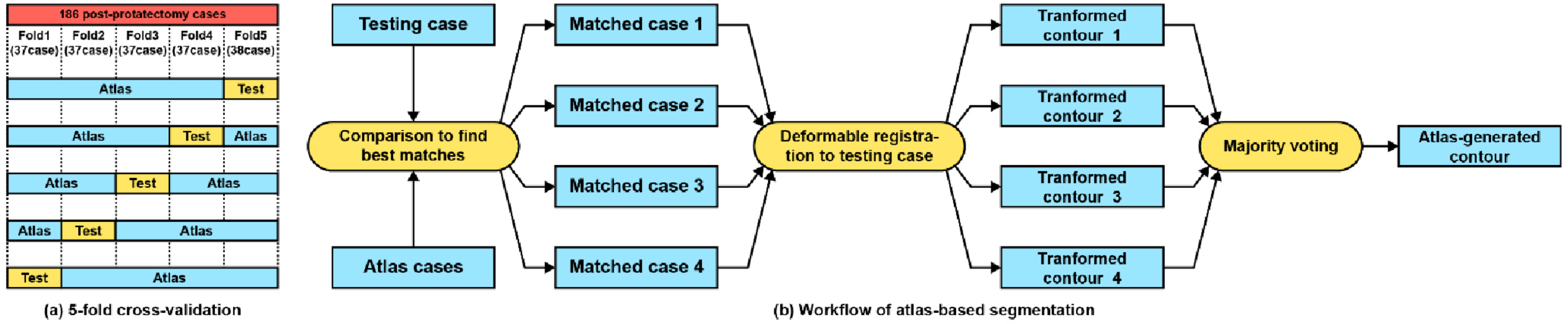

Fig. 1 *Schematic representation of (a) the 5-fold cross-validation and (b) the workflow of the atlas-based segmentation.*

RESULTS

The performance of auto segmentation is summarized in Table 1, and the distribution is visualized in Figure 2. The global DSC of the atlas-generated contours of the prostate bed, the bladder, and the rectum are **64.21±11.88%**, **64.07±17.48%**, and **61.75±11.54%**, respectively, and the global ASD are **4.81±11.40mm**, **7.65±15.27mm**, and **5.85±10.99mm**, respectively. The average segmentation time for all three structures is around **3 minutes** per CT image. Figure 3 shows six example cases with different DSC of the prostate bed (from 55% to 85%).

ROI	DCS [%]	ASD [mm]
Prostate bed	64.21±11.88	4.81±11.40
Bladder	64.07±17.48	7.65±15.27
Rectum	61.75±11.54	5.85±10.99

Table 1 *Summary of the segmentation accuracy of the atlas generated contours for the prostate bed, the bladder, and the rectum.*

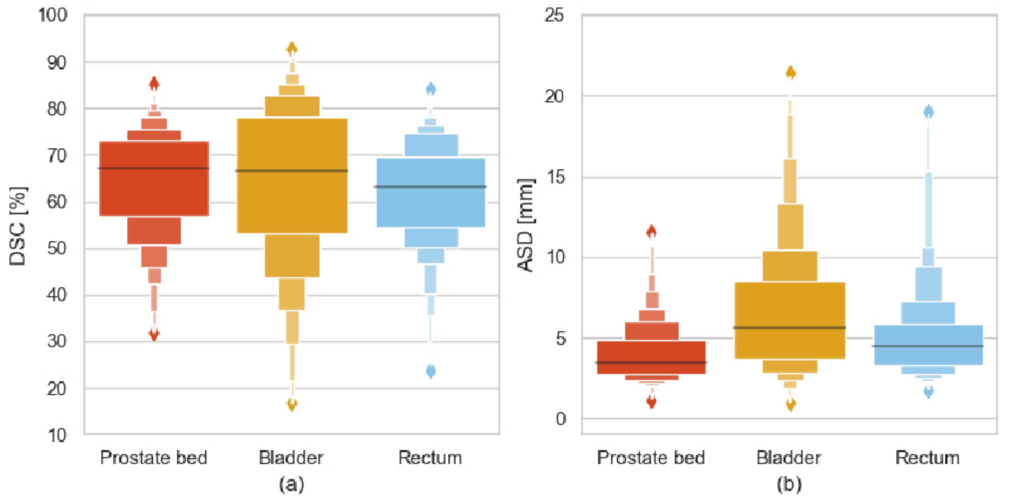

Fig. 2 *Boxplot of (a) DSC and (b) ASD for all testing cases.*

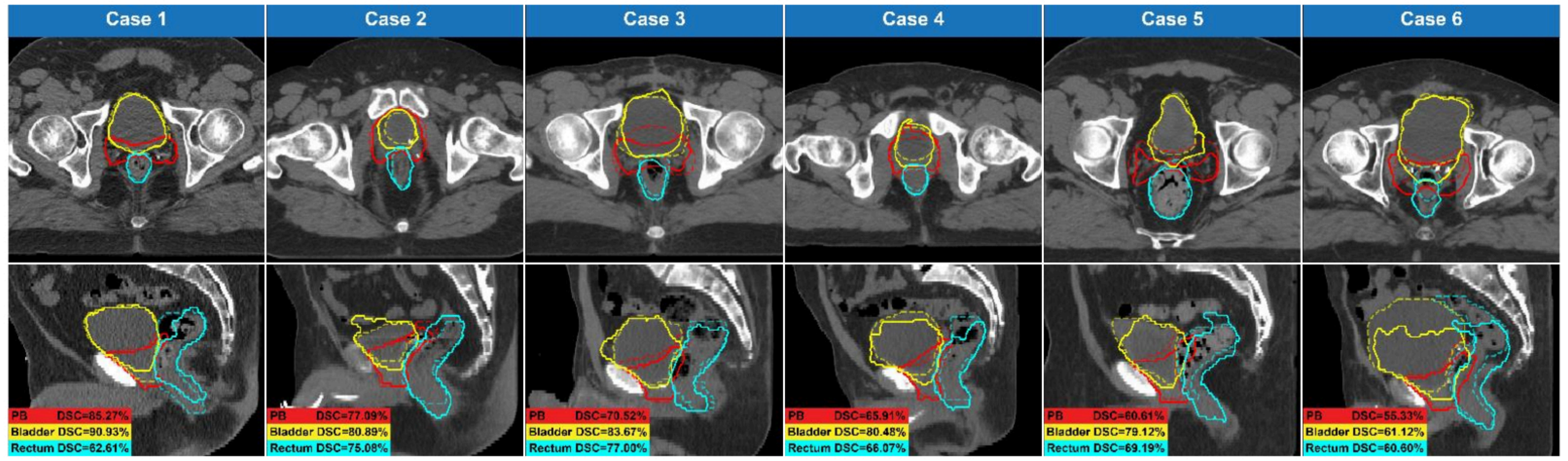

Fig. 3 *Visualization of sample cases with the prostate bed DSC varying from 55% to 85%. The dashed line is the control contour from the physician, while the solid line is the result of atlas-based segmentation.*

CONCLUSIONS

We built an atlas model and established a fully automatic workflow for prostate bed segmentation. Extensive experiments on an in-house dataset that consists of 186 post-prostatectomy cases show that our model can **segment the prostate bed and the OARs efficiently and reproducibly**. Although the final result still needs further improvement, it **can serve as a good initial contour** to save the manual contouring time in the planning procedure.

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