REGISTRATION ACCURACY OF AN INTEGRATED MR-TRUS NAVIGATION SYSTEM FOR PROSTATE HDR BRACHYTHERAPY

Topics: Prostate, Image-guidance

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Introduction

- A common treatment for long term disease control for prostate cancer is High-Dose-Rate (HDR) brachytherapy.
- A method to locate and incorporate the location of the epicenter of the cancer in treatment planning may improve the outcome of the procedure [1].
- Transrectal Ultrasound (TRUS) is a widely used imaging modality for guidance of brachytherapy procedures due to its ease of use, cost efficiency and real-time nature.
- To locate the tumor based on pre-identified MRI targets, a deformable registration between MRI and TRUS is needed [2].

- **<u>Objective</u>**: ***Evaluate an automated deformable registration performance of a prototype system for focal TRUS guided brachytherapy.***

Material and methods

- The system (Philips Disease Management Systems) was designed with the intent to support prostate tumor targeting through in-room image registration.
- The registration with this system is done between 3D prostate contours on both MRI and TRUS.
- Contours exported from the system custom software, with the deformable registration being performed live during the intervention [3].
- Common anatomical landmarks (urethra at the apex and base, cysts and calcifications) were identified in 3D on both TRUS and MRI by an experienced physician.

Computed metrics:

- Mean target registration error (mTRE) before and registration is reported.
- The determinant Jacobian matrix (DJM), which is a measure that shows the expansion or reduction of the deformation.
- For a physically possible deformation, this value is non-negative.
- The Dice coefficient computed between the prostate contours on TRUS and deformed contours from MRI.

Fig. 1: Setup of the PDMS (Philips Disease Management System) for HDR brachtherapy procedures. Includes the guidance system (right), US scanner (middle) and tracking system.

Results

- Registration accuracy was evaluated in 37 prostate HDR brachytherapy procedures.
- Multiparametric MRI (3D T2 SPACE, b2000 DWI, DCE) (n=11) were registered to PSMA-PET/CT (F^{18}DFCPyL) images (n=10) for segmentation (Eclipse, Varian) of the prostate boundary, urethra, and tumor PTVs.
- Tumor targets ranged from 1.3 to 34.4 cc (mean 8.8), and constituted 3.9-73.5% of prostate gland volumes (mean 17.5).
- After set-up, baseline interventional 3D TRUS images (BK) were obtained through manual sagittal sweep.
- Following automated deformable registration, the mTRE was found to 3.4 +/- 1.5 mm.
- The DJM was shown to be positive in all cases, yielding a Dice coefficient above 0.92.
- Two cases were excluded from the registration evaluation due to significant prostate deformation.

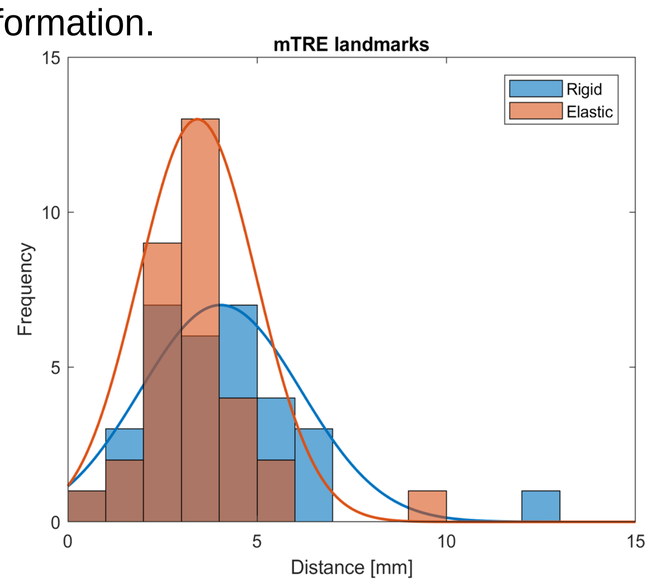

Fig. 2: Distribution of mean target registration errors, comparing errors between rigid and deformable (elastic) registration.

	37 prostate HDR brachytherapy procedures			
	Before		After	
	Ave.[mm]	SD [mm]	Ave. [mm]	SD [mm]
mTRE	4,04	2,12	3,43	1,56
Dice	0,81	0,08	0,94	0,02

Table 1: Accuracy metric based on mTRE and Dice coefficient, before and after deformable alignment.

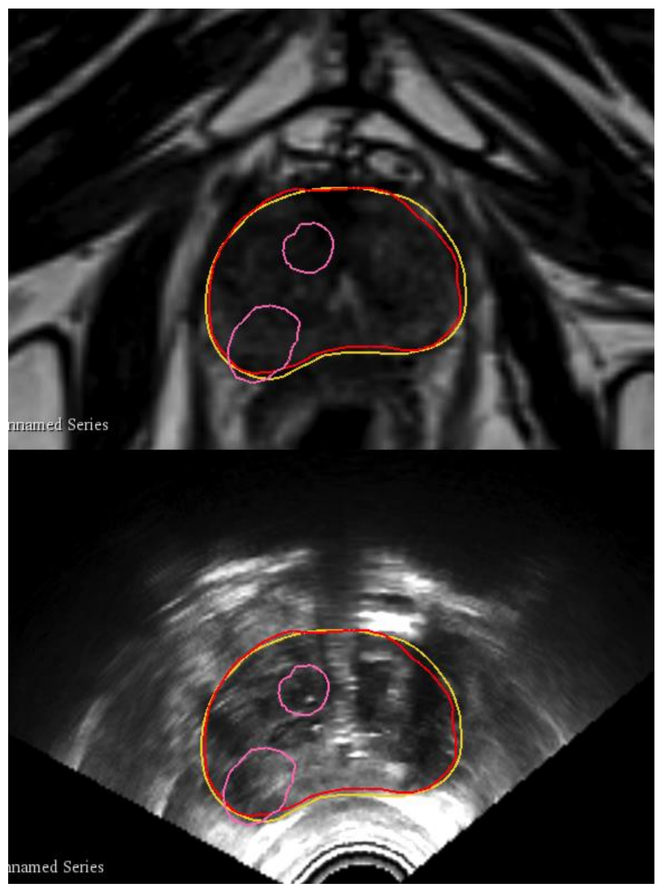

Fig. 3: Sample TRUS-MRI registration results. Contours in red and yellow describe the prostate boundaries on MRI and TRUS, respectively. Magenta represents tumor contours.

Conclusion

- Registration accuracy of this system was found to be in the clinical acceptable range for existing standard-care environments.
- Allows streamlined registration workflow while enabling tumor-targeting approaches.
- Future work will include:
  - Identify and address potential discrepancies in automated fusion;
  - Report on improvements in navigation accuracy with additional clinical experience.

References

[1] Pinto, Peter A., et al. "Magnetic resonance imaging/ultrasound fusion guided prostate biopsy improves cancer detection following transrectal ultrasound biopsy and correlates with multiparametric magnetic resonance imaging." The Journal of urology 186.4 (2011): 1281-1285.
[2] Poulin, Eric, et al. "Validation of MRI to TRUS registration for high-dose-rate prostate brachytherapy." Brachytherapy 17.2 (2018): 283-290.
[3] Klein, Stefan, et al. "Elastix: a toolbox for intensity-based medical image registration." IEEE transactions on medical imaging 29.1 (2009): 196-205.

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