# Multi-slice-to-volume registration for reducing targeting error during MRI-guided transrectal prostate biopsy

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## Introduction

### Context

- MRI-guided prostate biopsy workflow: Biopsy target points identified based on multi-parametric MRI review. Plan is warped to the intra-procedural configuration in the beginning of the procedure. [1]
- Intra-procedural motion of the prostate gland may dislocate the target points, leading to targeting errors.
- Registration of the planning image to intra-procedural scan showing the deformation can be used to reduce errors in needle placement.
- Most of the existing methods are impractical for routine clinical use because they require lengthy acquisition of volumetric images.

### Purpose

- Evaluate a deformable image registration approach that relies on sparse MR imaging to recover motion and deformation of the prostate during MR-guided biopsy.

## Registration method

### Pre-processing

- Intensity inhomogeneity correction
- Sparse volume construction (Fig. 1.)

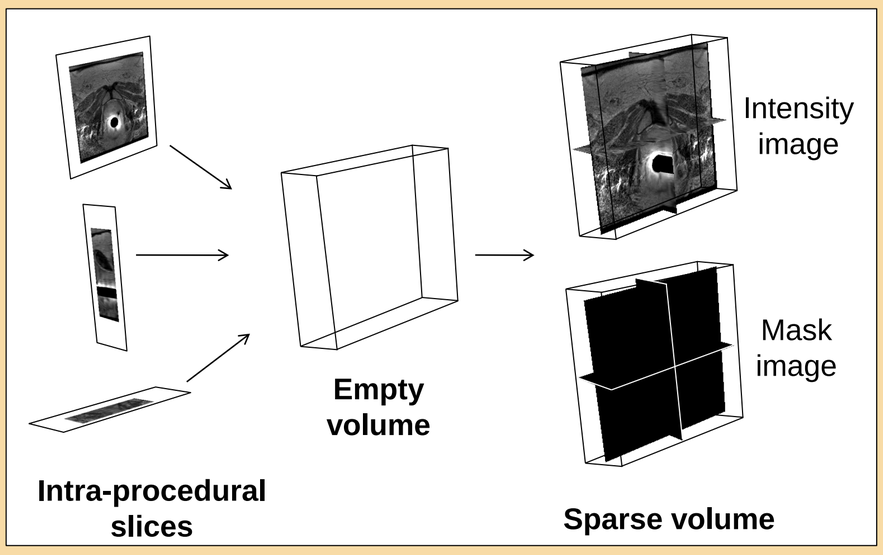


**Figure 1:** A sparse volume is created from a few intra-procedural slices

### Registration

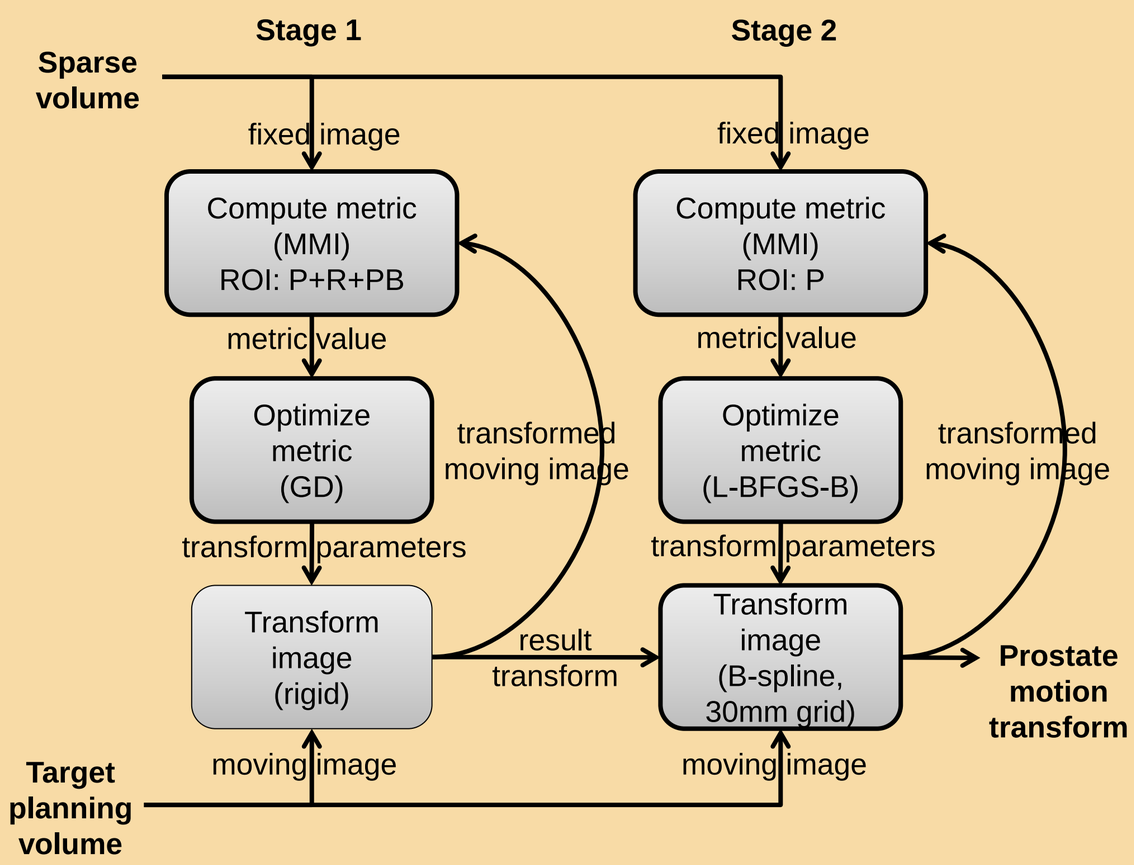


**Figure 2:** Overview of the slice-to-volume registration algorithm. *MMI*: Matter Mutual Information; *ROI*: region of interest. *P:* prostate, *R:* rectum, *PB:* pubic bone; *GD*: gradient descent; *L-BFGS-B:* limited-memory Broyden–Fletcher–Goldfarb–Shannon optimizer with simple bounds.

## Evaluation method and results

### Imaging

- Clinical images of one patient, acquired by a Siemens Magnetom Verio 3T scanner.
- Target planning volume: axial T2w TSE sequence (320x320x320 voxels, 0.625x0.625x4.8mm voxel size)
- Intra-procedural slices: HASTE protocol (320x244 voxels, 0.94x0.94x3.6mm voxel size, 18 seconds acquisition time) and TrueFISP protocol (320x320 voxels, 1.25x1.25x3.6mm voxel size, 7 seconds acquisition time).

### Evaluation

- Accuracy of the registration was qualitatively assessed by comparing the manually segmented prostate gland contours on the planning and slice images with and without registration.
- Robustness of the rigid registration step was evaluated by performing repeated registrations with the randomly perturbed initial transformation (±20mm translation and ±10° rotation).

### Quantitative results

- Distance between the contours without registration: up to 3-4mm.
- With rigid registration: reduced to about 1-2mm.
- With additional non-rigid registration: reduced to about 1mm.
- In 95% of the experiments evaluating robustness, the registration result was within 0.4 mm translation and 0.5° rotation difference as compared to the non-perturbed result in case of the HASTE protocol, and within 1.8 mm and 2.5° difference with the TrueFISP.
- Average computation time. Rigid registration step: 3 seconds. Non-rigid step: 12 seconds.

### Qualitative results

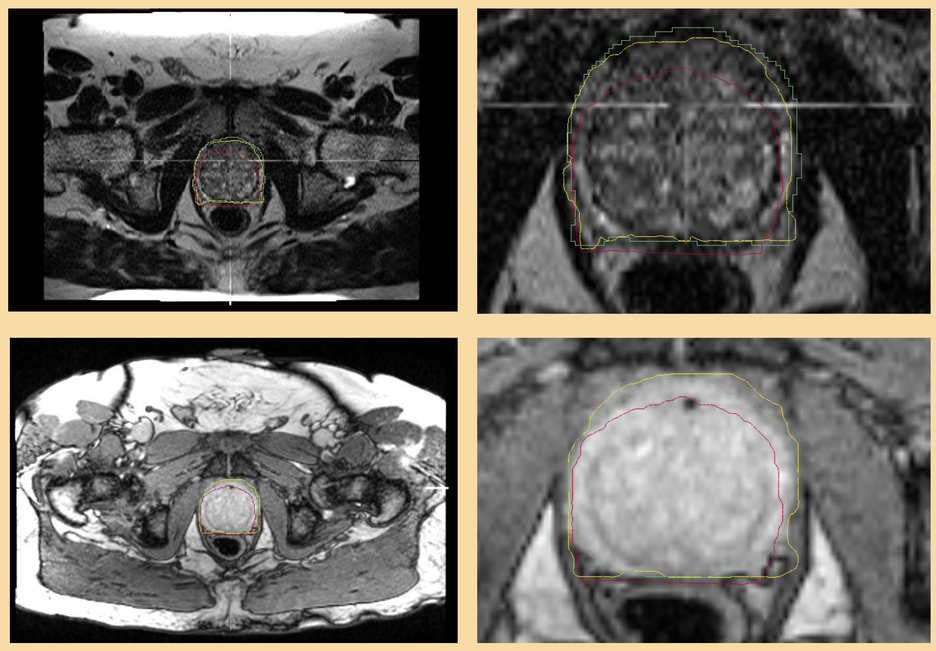


**Figure 3:** Prostate contours from the target planning volume overlaid on the axial intra-procedural slice.
Left column: whole slice. Right: column: prostate region magnified.
Contour colors: Red: without registration. Orange: rigid registration.
Green: deformable registration

## Conclusions

- The proposed registration technique may be able to estimate the prostate motion and deformation during MRI-guided prostate biopsy procedures by a quick multi-slice acquisition followed by a fully automatic computation step.
- Further testing on more patients is needed to confirm the results.

## References

[1] Tuncali, K., J. Tokuda, I. Iordachita, S S-E. Song, A. Fedorov, S. Oguro, A. Lasso, F. M. Fennessy, Y. Tang, C. M. Tempany, et al., "3T MRI-guided Transperineal Targeted Prostate Biopsy: Clinical Feasibility, Safety, and Early Results", ISMRM 2011, vol. 19, pp. 53, 2011.

[2] Tadayyon H, Lasso A, Kaushal A, Guion P, Fichtinger G. 2011. Target Motion Tracking in MRI-guided Transrectal Robotic Prostate Biopsy. IEEE Transactions on Biomedical Engineering. 58:3135-42.