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

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Purpose

MRI has been shown to be a valuable tool for guiding prostate biopsy. Biopsy target points are selected in an image acquired at the beginning of the procedure. Intra-procedural patient motion dislocates the target points, which results in targeting error. Image registration methods can be used to estimate the patient motion. If the patient motion is known then the actual target positions can be computed, which results in reduced targeting error. Most of the existing registration methods require lengthy volumetric image acquisition. A method that can recover the prostate motion from only a few image slices may better fit into the interventional workflow and could be utilized frequently during interventions.

Methods

A registration method was developed to align the volumetric image that was used for planning to a set of orthogonal image slices that were acquired right before needle insertion. The registration method is composed of a preprocessing step and two registration stages. The preprocessing step involves intensity inhomogeneity correction using the N4ITK method and construction of a sparse volumetric image from the image slices. The first registration stage is a rigid registration to obtain an initial pose of the target planning volume, which is then non-rigidly registered to the fixed sparse volume in the second stage. Mutual information is used as similarity metric. A grid with 30mm spacing between the control points and B-spline interpolation is used to model the deformation. Simple gradient descent and L-BFGS-B optimizers are used in the first and second stages, respectively.

Results

The intra-procedural prostate motion compensation method was tested on simulated and clinical images using three orthogonal intra-procedural slices. Simulation results showed that the slice-to-volume registration reduced the initial (without registration) error of 2.1–5.6 mm to as low as 0.6–0.9 mm. Testing on clinical images taken during 4 different MRI-guided robot-assisted prostate biopsy procedures resulted in a mean registration error of about 1mm. Average computation time of the registration was about 40 seconds.

Conclusions

The proposed registration technique is a promising method for reducing the targeting error during MRI-guided prostate biopsy procedure, which provides considerable error reduction, without requiring lengthy volumetric image acquisitions. The next step in this work is extensive testing of the algorithm on image slices acquired during clinical procedures.