Planning and Targeting System for MRI-guided Robotic Interventions

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Purpose: Several robotic devices have been developed for MRI-guided interventions in the past few years. Some have progressed to use in clinical procedures. One pertinent problem in the research, development, and testing of these systems is that typically enormous engineering efforts are required for implementing any change in the interventional procedure or hardware devices. Our purpose was to minimize these efforts by creating a system platform that can be easily adapted to implement various MRI-guided robotic interventions. We chose to first evaluate the platform on prostate biopsy procedures.

Methods: A planning and targeting system platform was designed based on our earlier experience in designing and implementing robotic interventional devices. The system is composed of reusable, interchangeable components, connected using open communication protocols, and implemented using open-source software components. The graphical user interface for planning and targeting is implemented using the 3D Slicer application framework, extended with custom plug-in modules. The application communicates with the robot controller and the imaging device using OpenIGTLink and DICOM networking protocols. Specialized device models, calibration methods, and patient motion compensation technique were developed for prostate biopsy interventions. The motion compensation method uses image-based deformable registration and requires acquisition of only a few image slices. The method allows frequent intra-procedural verifications and corrections of the target positions.

Results: An extensible planning and targeting system was developed that works with three different needle positioning devices for MRI-guided prostate interventions (Fig. 1). The system has been successfully used on patients at multiple hospitals. The motion compensation method was integrated into the software framework and tested extensively on simulated and real patient data. Simulation results showed that the registration reduced the initial error of 2.1–5.6 mm to 0.6–0.9 mm (Fig.2.). Initial testing on clinical images indicates a mean in-slice registration error of about 1mm.

Conclusions: The proposed platform can reduce the required engineering efforts for developing and testing new MRI-guided interventional planning and targeting systems. The concept was demonstrated successfully by developing a system for prostate biopsy procedures with intra-procedural patient motion compensation.

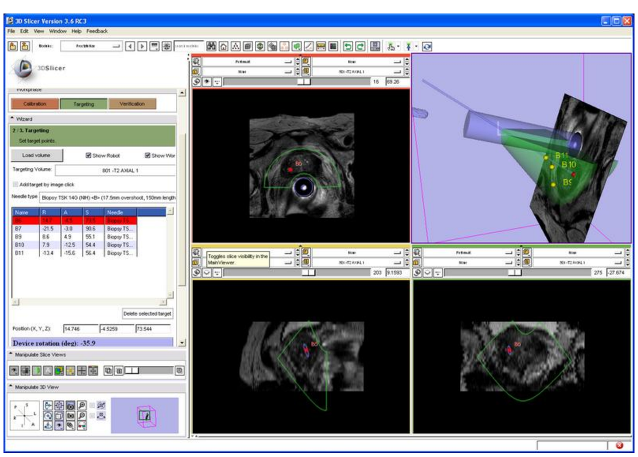

Figure 1. Screenshot of the planning and targeting software used for MRI-guided prostate biopsy

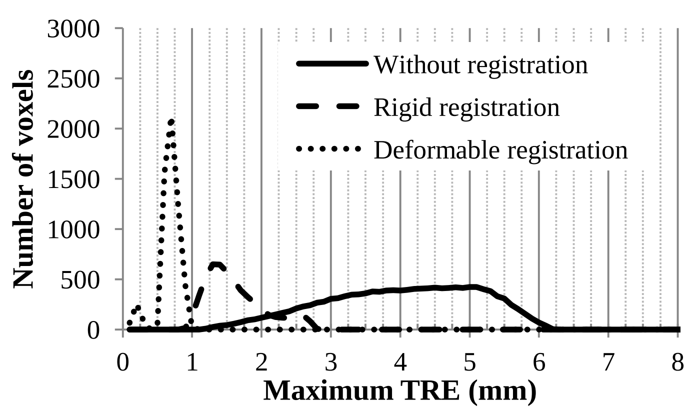

Figure 2. Maximum target registration error (TRE) computed in the whole prostate gland from simulated deformations