Towards teleoperated needle steering in MRI-guided prostate interventions

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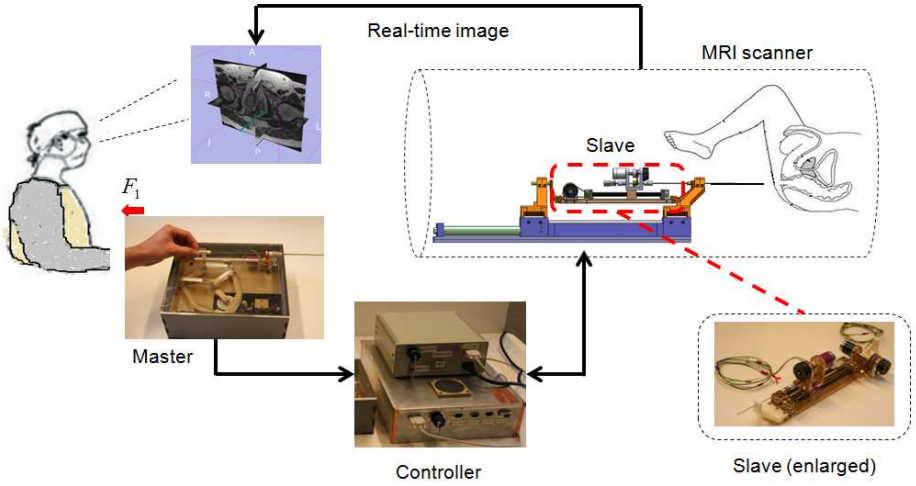
Purpose: Prostate biopsy and brachytherapy involve needle insertion into the prostate. During the insertion, prostate gland rotates and deforms which may cause displacement of the target tissue. We propose robot-assisted bevel-tip needle steering under MRI guidance as a potential solution. This approach promises to reduce needle placement and allows the clinician to insert needles without removing the patient from the scanner, thereby also shortening the procedure.

Methods: The system components are shown in the figure below. We designed and built a 2 degree of freedom (DOF) MRI-compatible master robot and a 2-DOF MRI-compatible needle steering slave robot. The standalone master console is placed next to MRI scanner, while the slave is incorporated with a previously developed in-scanner transperineal pneumatic robot. A controller box including controller hardware, motor drivers, and optical convertors connects the master and slave, ensuring position and force tracking between them. Both the master and slave use MRI-compatible piezoelectric motors. Optical encoders are used as position sensor.



Results: The master and slave were designed and built. The slave provides linear travel of 140 mm and rotation of 360 degrees for the needle. The master provides similar range of motion using a Peaucellier-Lipkin linkage. The insertion velocity is 7 mm/sec and the maximum force at the needle tip is 4N, deemed adequate for the task. A 4-axis Galil motion controller is used for the master-slave system. The system was tested for speed and force capability on a prostate implant phantom. PD controller was implemented on the slave side and it provided satisfactory position tracking.

Continuing Work: Fiber Brag Grating (FBG) force sensors are being currently implemented to provide haptic feedback for the operator's hand and the controller is being adapted to ascertain simultaneous force and position tracking between the master and slave.