Real-time tracking for MR-guided breast biopsies: dream or reality?

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Target Audience: Researchers/clinicians interested in MR-guided breast biopsies

Introduction: MR-guided breast biopsies are now an important part of a breast imaging program. They can be lengthy, expensive procedures, whose accuracy and false negative rates are of concern [1]. One of the reasons for their complexity is the fact that they are conducted without real-time guidance; the lesions can be visualized for ~10 - 20 minutes after the contrast agent is injected, while the patient is in the MRI magnet. Biopsies are, however, performed outside the MRI magnet, with the women on the MRI table. One or more image confirmation steps are usually performed, to insure that the intended tissue has been biopsied. The goals of the work presented here were twofold. First, preliminary data was collected to assess breast immobility during the biopsy procedure, hence determine if sole instrument tracking (i.e. in the absence of real-time imaging) is sufficient for lesion targeting. Secondly, the suitability of electromagnetic (EM) tracking, a technology commonly used in ultrasound guided biopsies, was assessed for real-time visualization of instrument positioning in the strong, position dependent fringe field of the MRI magnets.

Methods: To assess breast immobility during the breast biopsy procedure, four pre- and -post biopsy patient data sets were analyzed. After performing non-linear registration between the first (contrast) series and the last series in the biopsy exam (confirming biopsy location), we recorded pixel displacement for all voxels and all patients.

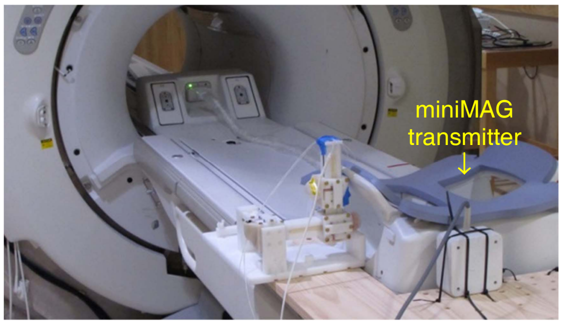

Figure 1: Setup of the preliminary tracking experiments

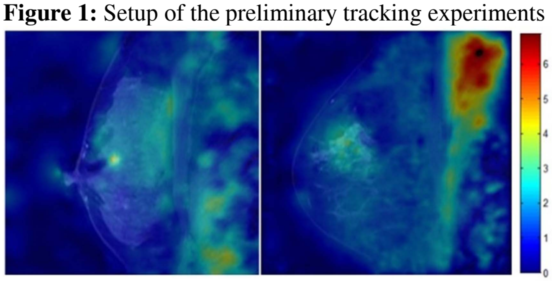

Figure 2: Tissue displacements [mm] recorded between the start and end of biopsy exams in 2 patients

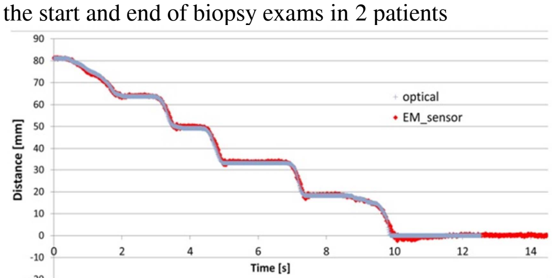

Figure 3: Distance as function of time for optical (blue) and EM (red) sensors

Our tracking experiments were performed in the fringe field of a 3T, MR750 GE scanner (Waukesha, WI), where biopsies are usually conducted, next to the 8 channel, GE breast coil. An EM tracking system, containing a miniMAG pulsed DC transmitter and a modified sensor, were used (Figure 1). The sensor, of 2.4mm outer diameter and 4.5mm length, was a solenoid coil, with its ferromagnetic core removed. The EM sensor was mounted to a translation stage, containing an optical encoder that could report position with 0.1mm accuracy.

Results and Discussion: Figure 2 displays the displacements recorded in a slice from 2 patients. The average voxel displacement over the breasts of 4 patients during the biopsy procedure was 0.8mm (with higher, up to 3.5mm, displacements seen around the biopsy site). Note that the typical, 9-gage vacuum assisted biopsy tools have ~4mm diameters, and large displacements around their tracks were expected. These low displacements confirmed that the rigid geometry assumption is warranted, and that instrument tracking is likely sufficient for real-time monitoring of the procedure.

Figure 3 shows the sensor position as a function of time, reported by the optical encoder (blue) and the EM sensor (red). Note the exquisite position assessment of the EM tracking system, indicating this approach as very promising for instrument tracking during MR-guided breast biopsies. It is to be noted, however, that some EM tracking transmitters/receivers contain ferromagnetic cores, to increase their inductance, hence their tracking range. This can create a safety hazard in a MRI room; for our experiments, e.g., the transmitter was strapped to the MRI table. Removal of the ferromagnetic cores will lead to a reduction in the tracking range. Increasing the transmitter and sensor dimensions can, to a large extent, compensate for this reduction. The tracking range of an Aurora NDI system (coupled to a ferromagnetic cored sensor) is 66cm; removal of the ferromagnetic core from the receiver reduces this range to ~33cm. Extending the length of the RF coil from the current 4.5 to 9mm could enable increasing the tracking range to ~42cm. Changing to finer wire, adding more layers of turns and/or increasing the receiver diameter could increase the tracking range to 50cm, sufficient for a breast biopsy procedure.

Conclusions: This work presents preliminary evidence, confirming breast immobility during the MR-guided biopsy procedures, and suggesting that EM tracking is feasible in the strong fringe field of 3T MRI magnets. Retrofitting breast biopsy tools (such as stylets or biopsy guns) with EM sensors could enable real time visualization of tool advancement towards the lesion, hence significantly increase the accuracy and decrease the time needed for MR-guided breast biopsy procedures.

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References: [1] Bahrs et al, Clin Radiol 2014;69(7):695-702.