Monitoring electromagnetic tracking error in computer-navigated breast cancer surgery

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Introduction. Lumpectomy, or breast conserving surgery, is done to remove cancerous tissue from the breast. Computer navigation using electromagnetic (EM) tracking can ensure that all cancerous tissue is excised[1], however electromagnetic tracking is error-prone. Ferromagnetic objects and the position of the electromagnetic field generator can lead to tracking error and the possibility of an incomplete resection. Therefore, it is crucial to monitor tracking error in clinical environments, not just in navigated lumpectomy procedures but in all image-guided interventions using EM tracking. Our goal was to develop and test a system to monitor electromagnetic tracking error for computer-navigated interventions in an accessible and open-source fashion.

Methods. A pointer tool was designed for simultaneous electromagnetic and optical tracking. Optical tracking can be used to estimate positional and rotational electromagnetic tracking error since it is unaffected by ferromagnetic objects. The PLUS software toolkit's[2] PlusServer application sent tracking data to 3D Slicer. Software modules were developed for automatic calibration of the measurement system, real-time error visualization, and analysis as an extension for 3D Slicer. In order to measure EM tracking error, a measurement tool, software module, and optical tracker were added to the navigation system (Figure 1, Left). In an operating room environment, we tested for field distortion in a computer-navigated lumpectomy set-up.

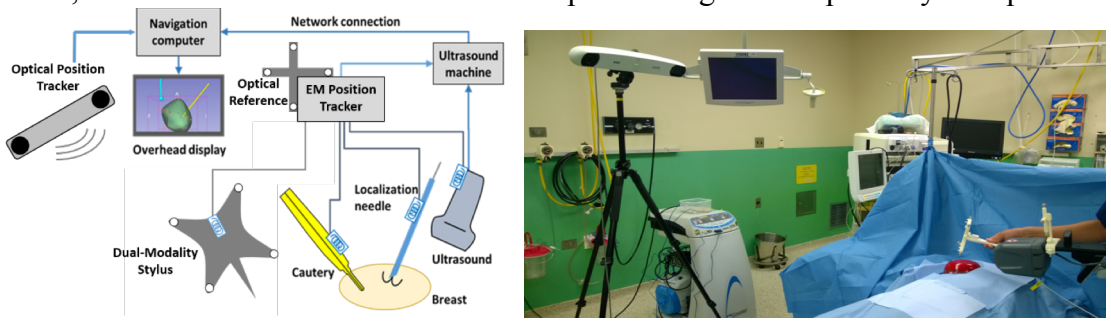

Figure 1. Hardware configuration diagram of the breast surgery navigation system augmented with EM tracking measurement tools (Left). The system as it appears in the operating room (Right).

Results. Setup and deployment of our system is quick and easy. In only a few minutes, users can calibrate our system and obtain quantitative values for tracking error or qualitative depictions of tracking error within a region of interest using 3D Slicer's Transform Visualizer (Figure 2)[3]. Tracking error in a clean field without any surgical equipment was approximately 0.90 mm (positional) and 0.31° (rotational). The presence of an electrosurgical cautery, a surgical table, and anesthesia machine caused negligible increases in error. Both the positional and rotational error only increased by a few tenths of a millimeter or few tenths of a degree in these cases.

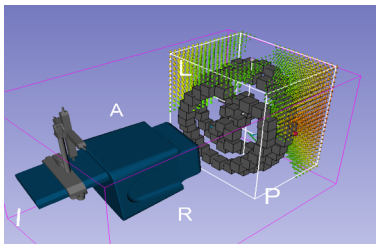

Figure 2. Real-time display of electromagnetic tracking error.

Conclusion. Our open-source system is available as an extension for 3D Slicer. CAD files for our designed hardware tools are also available on the PLUS Model Catalog. As demonstrated in a computer-navigated lumpectomy set-up, our system can be used to quantify electromagnetic tracking error in the operating room.

References. [1] Ungi *et al.*, Real Time Navigation in Breast Tumor Surgery, *International Journal of Computer-Assisted Radiology and Surgery*, vol. 10, no. 3, pp. 253-62, 2015. [2] Lasso *et al.*, PLUS: open-source toolkit for ultrasound-guided intervention systems. *IEEE Trans Biomed Eng.*, vol. 61, no. 10, pp. 2527-37, 2014.[3]King *et al.*, A tool for intraoperative visualization of registration transformations. Proc. SPIE 9036, Medical Imaging 2014: Image-Guided Procedures, Robotic Interventions and Modeling, 90362A (March 14, 2014).