A platform for robot-assisted intraoperative imaging in breast conserving surgery

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INTRODUCTION: Breast conserving surgery is a procedure that involves removing a cancerous lesion from the breast while preserving the surrounding healthy tissue. The outcomes of these surgeries are more psychologically and cosmetically favourable when compared to treatment options like partial or full mastectomy where the entire breast is removed. A main shortcoming of these procedures is that precise tumor delineation is difficult whenever a tumor is irregularly shaped, non-palpable or if the surgeon has restricted visual access to the incision site. Recent advancements in optical, acoustic and biochemical imaging approaches such as spectroscopy, ultrasound and mass spectrometry, enable intraoperative tissue assessment as a potential solution to this problem [1]. With the assistance of machine learning, imaging data can be used to identify a cross section of tissue as either cancerous or healthy. However, effective use of these imaging tools is limited by the surgeon's ability to thoroughly scan the resection cavity by hand and retrace their motion to perform additional resection if necessary. Therefore, in this work we propose a robotic framework that can be used to deploy these imaging tools in breast cancer surgery. The system itself is unique when compared to existing surgical robotic devices that are designed for robust control and force feedback. As the breast itself poses practically no resistant force on the surgeon's tools, we made use of an inexpensive haptic manipulator and began the integration of this device with navigation technology.

METHODS: Our system consists of the Omni Bundle robot by Quanser, an electromagnetic tracking system, an imaging tool (spectrometer) and a mechanical retractor. The system is interfaced with the open-source medical imaging platform 3D Slicer (www.slicer.org) to enable real-time visualization of the robot and the surgeon's tools with respect to the breast, which is also electromagnetically tracked (Figure 1). A module was developed in 3D Slicer to display a 3D model of the robot as it moves, as well as models of the electromagnetically tracked surgical tool and retractor. In the experimental prototype, an optical spectrometer replaces the imaging tool, distinguishing variations in color inserts placed in a silicon breast phantom. To account for breast deformity, the EM sensor on the retractor is considered a moving reference to the breast.

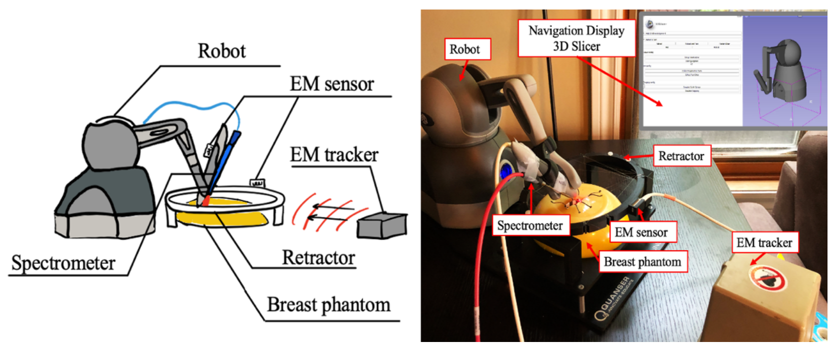

Figure 1: Hardware setup for the new platform.

RESULTS: We were successful in developing a proof-of-concept platform that enables cooperative robotic guidance of an imaging tool through a resection cavity, with real-time visual navigation and display. We evaluated the system based on the performance of the module in 3D Slicer.

CONCLUSIONS: This platform will serve as the basis for a navigation system that combines novel imaging tools and robotic assistance. Clinical implementation will likely improve the accuracy of breast conserving surgery and reduce the risk of incomplete resections. The system is also open-source and flexible so it can be translated to other institutions. Moreover, the proposed technology may also be extended to other areas of surgical oncology. Future work includes implementing more sophisticated control algorithms for the robot to fully scan the cavity.

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