Intraoperative user interface for navigated breast tumor surgery

T. Ungi[1,2], T. Vaughan[1],G. Gauvin[2], P. Pezeshki[2], A. Lasso[1],
C. J. Engel[2], J. Rudan[2], G. Fichtinger[1,2]

[1] Queen's University, School of Computing, Kingston, ON, Canada
[2] Queen's University, Department of Surgery, Kingston, ON, Canada

Purpose: Breast conserving surgery is the most common therapy for early stage breast cancer. However, the first procedure often fails to remove the entire tumor. Studies report 15-50% rate of incomplete excisions, when patients undergo another surgery to extend the margins of the first excision attempt. Breast conserving surgery can be navigated by tracking the surgical cutting device and the tumor through a localization wire [1]. This method was found safe and feasible in patients, and is currently under clinical evaluation for effect on success rate in non-palpable breast tumor cases. The next step in the clinical translation process is to develop a user interface that does not require technical staff in the operating room. Operators need to interact with the software through sterile gloves, they need to define tumor margins using tracked ultrasound, and the 3-dimensional visualization scene needs to be adjusted to the operator‘s point of view. We addressed these issues by providing an open-source solution that can be reused in similar clinical applications.

Methods: We implemented a minimal graphical user interface for the 3D Slicer application core functions, with components commonly needed in image-guided medical interventions. Buttons for interactions were optimized for touchscreen tablets. They can be used through sterile bags and surgical gloves. Tumor contouring interactions were designed for holding the ultrasound scanner in one hand and operating the touchscreen with the other hand. While the operator touches the visible tumor margins on the ultrasound image, a 3-dimensional margin model is automatically updated using the position tracker of the ultrasound. Virtual camera orientations for navigation scenes are set up by touchscreen interactions and positioning the surgical cutting device in the line of sight of the surgeon. The intraoperative interface for breast tumor surgery was tested by eight surgical residents on synthetic phantoms (Figure 1). Their experience was measured on a semi-quantitative 5-grade rating scale from worst (1) to best (5). Conventional keyboard and mouse served as control method in our study. Tracking and imaging hardware devices of the navigation system were handled by the PLUS toolkit [3]. Reusable components of the navigation system were implemented in the SlicerIGT extension (www.slicerigt.org) of the 3D Slicer application platform. 3D Slicer (www.slicer.org) offers a convenient plug-in mechanism with an app store [2].

Results: The surgical navigation software for breast cancer was developed in the Python programming language as an extension of 3D Slicer. It is available in 3D Slicer, and the source code is available in a public repository (https://github.com/SlicerIGT/LumpNav) with a license that allows modifications, commercial and academic use without restrictions. Hardware devices for sterile operation technique have been developed and shared as editable model files in the PLUS toolkit (www.plustoolkit.org). These models can be replicated with a 3D printer. Users found the navigation software to be more conveniently usable with the intraoperative interface compared to keyboard and mouse interface: 5 (4-5) vs. 2 (2-2.5), $p<0.01$ (median, 25%-75% percentiles, Mann-Whitney test). Users found intraoperative tumor contouring easy to perform: 4 (4-4.5), and they were satisfied with the duration of the procedure with the new interface: 4 (4-4.5).

Conclusion: Navigated breast tumor surgery is feasible using an intraoperative touchscreen user interface without additional technical staff. The presented interface was rated significantly better than conventional keyboard and mouse. The navigation software with intraoperative touchscreen is currently under clinical testing in breast cancer surgery (Figure 2).

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References

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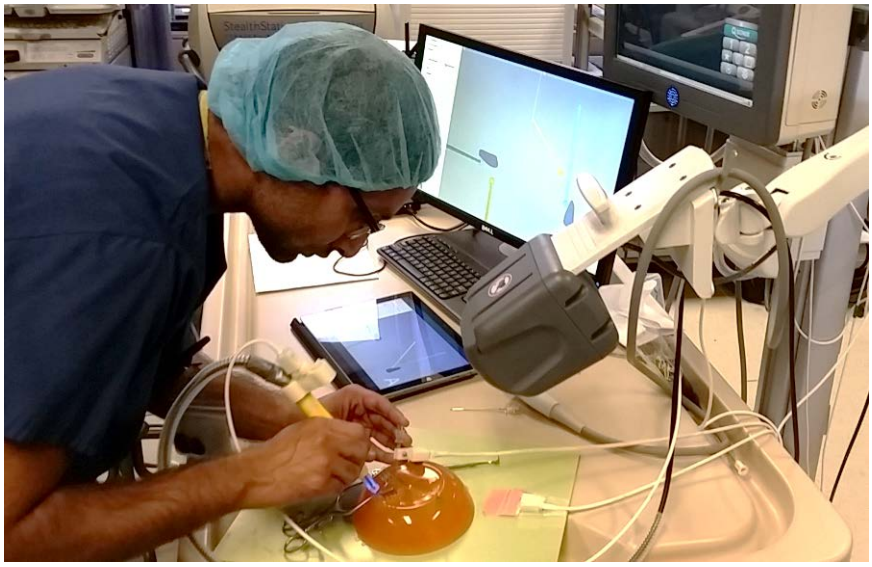

Figure 1. Experiment for testing of the intraoperative user interface on plastic phantoms.

Figure 2. Intraoperative touchscreen user interface during tumor contouring (left) and excision navigation (right).