PLUS: An open-source toolkit for ultrasound-guided intervention systems development

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Purpose: Ultrasound-guided intervention systems require the integration of many hardware and software components, such as ultrasound scanner, position tracking device, data processing algorithms, and visualization software. The objective of this work is to provide a free and sharable software toolkit – PLUS (Public software Library for UltraSound) – to facilitate rapid prototyping of ultrasound-guided intervention systems for translational clinical research.

Methods: The open-source *SynchroGrab* library for tracked ultrasound capturing and 3D reconstruction was released in 2008. We redesigned this monolithic library into a modular toolkit, each component was thoroughly tested, fixed, and enhanced, and several new functionalities were added. The toolkit now offers automatic spatial and temporal calibration methods. Standard data formats are used for streaming (OpenIGTLink) and storage (MetaIO image format with additional custom fields for storing pose information). Building of the toolkit is fully automated, using CMake to download and build all required software libraries. PLUS can be used for building standalone applications, extensions for 3D Slicer, or communicate with 3D Slicer modules through OpenIGTLink protocol (**Fig. 1.**). A set of tests are automatically executed after each submitted software change to verify the main functionalities of the toolkit (using CTest/CDash). Source control, documentation, issue tracking, message boards are all integrated and managed on a public website.

Results: PLUS currently supports RF and B-mode ultrasound image acquisition using Ultrasonix devices and B-mode image acquisition on devices with an analog video output. Position tracking is supported for Ascension, NDI, and Claron optical and electromagnetic trackers and several digitally encoded prostate brachytherapy steppers. Numerous readily usable applications were developed for tracked ultrasound capturing, calibration, 3D reconstruction, real-time display, and streaming (**Fig. 2.**). The toolkit is used by research groups at Queen's University, University of British Columbia, and Robarts Research Institute for prototyping prostate and spine intervention systems. The toolkit has a BSD-type license, which allows free usage and modification, even for commercial use. Source code, documentation, sample data, and releases are available at **https://www.assembla.com/spaces/plus/**.

Conclusions: The proposed toolkit has proven to be useful for developing ultrasound-guided intervention systems. We are working on continuous improvement of PLUS and looking forward to seeing more research groups using, improving, and extending the toolkit.

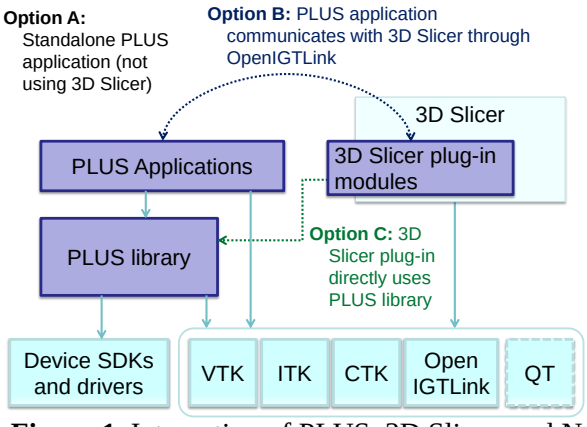

Figure 1. Integration of PLUS, 3D Slicer, and NA-MIC kit libraries to create software applications

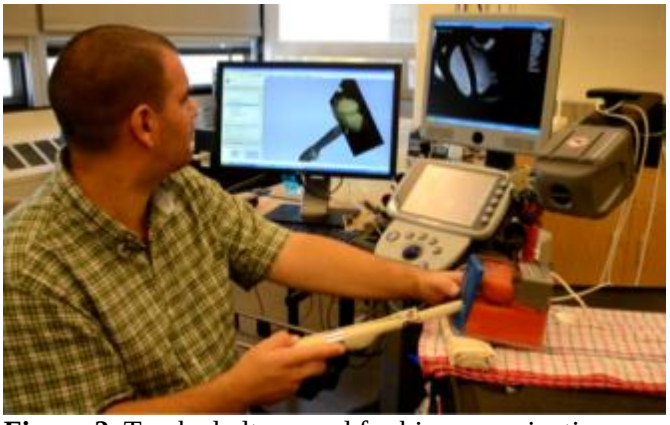

Figure 2. Tracked ultrasound for biopsy navigation with 3D Slicer