Real-Time Data Acquisition for Cardiovascular Research

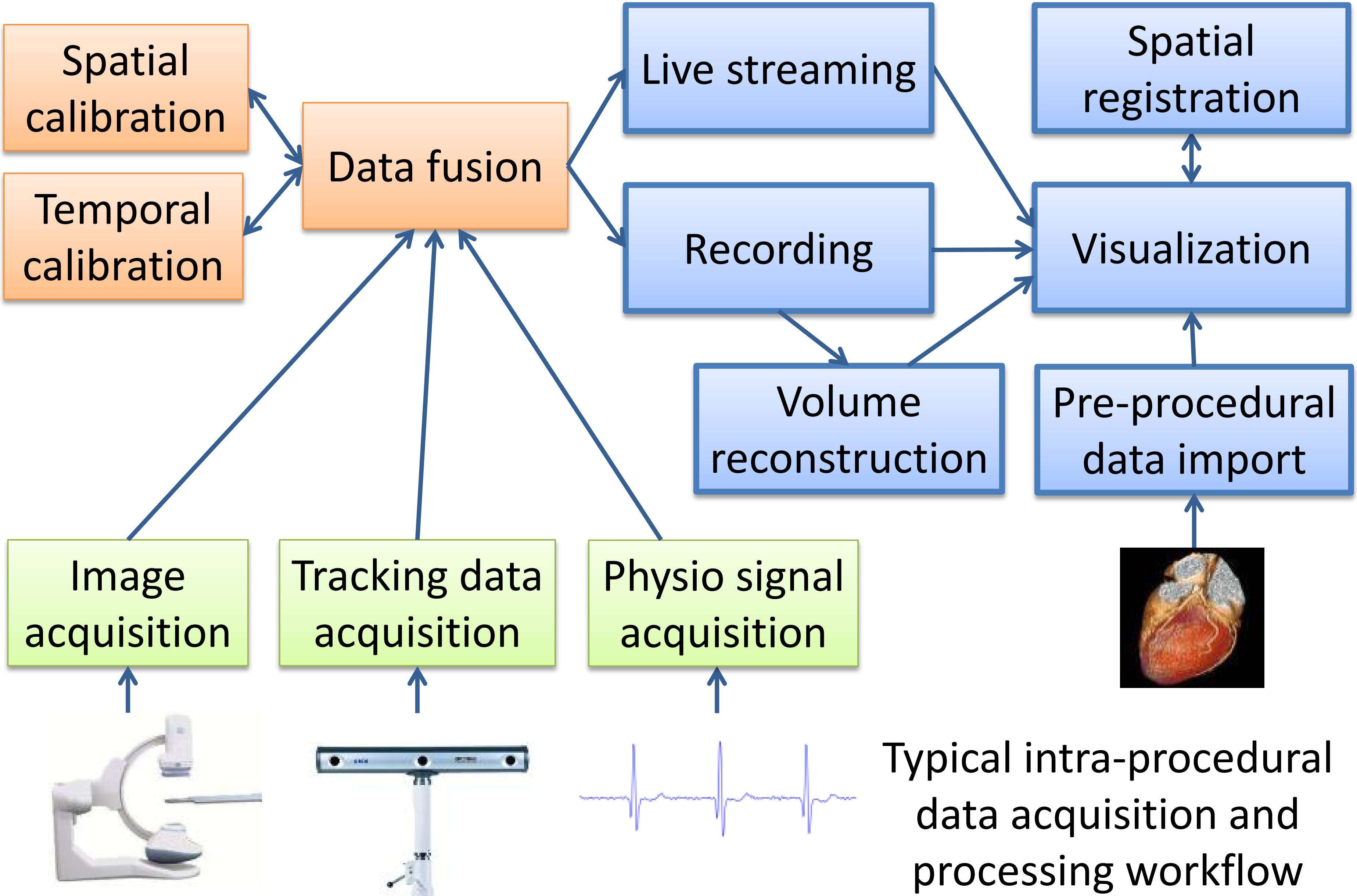
Andras Lasso, PhD

Laboratory for Percutaneous Surgery

School of Computing, Queen’s University, Kingston

Questions / challenges

- What hardware/software interfaces to use?
- How to calibrate the system?
- How to implement basic data visualization and processing?

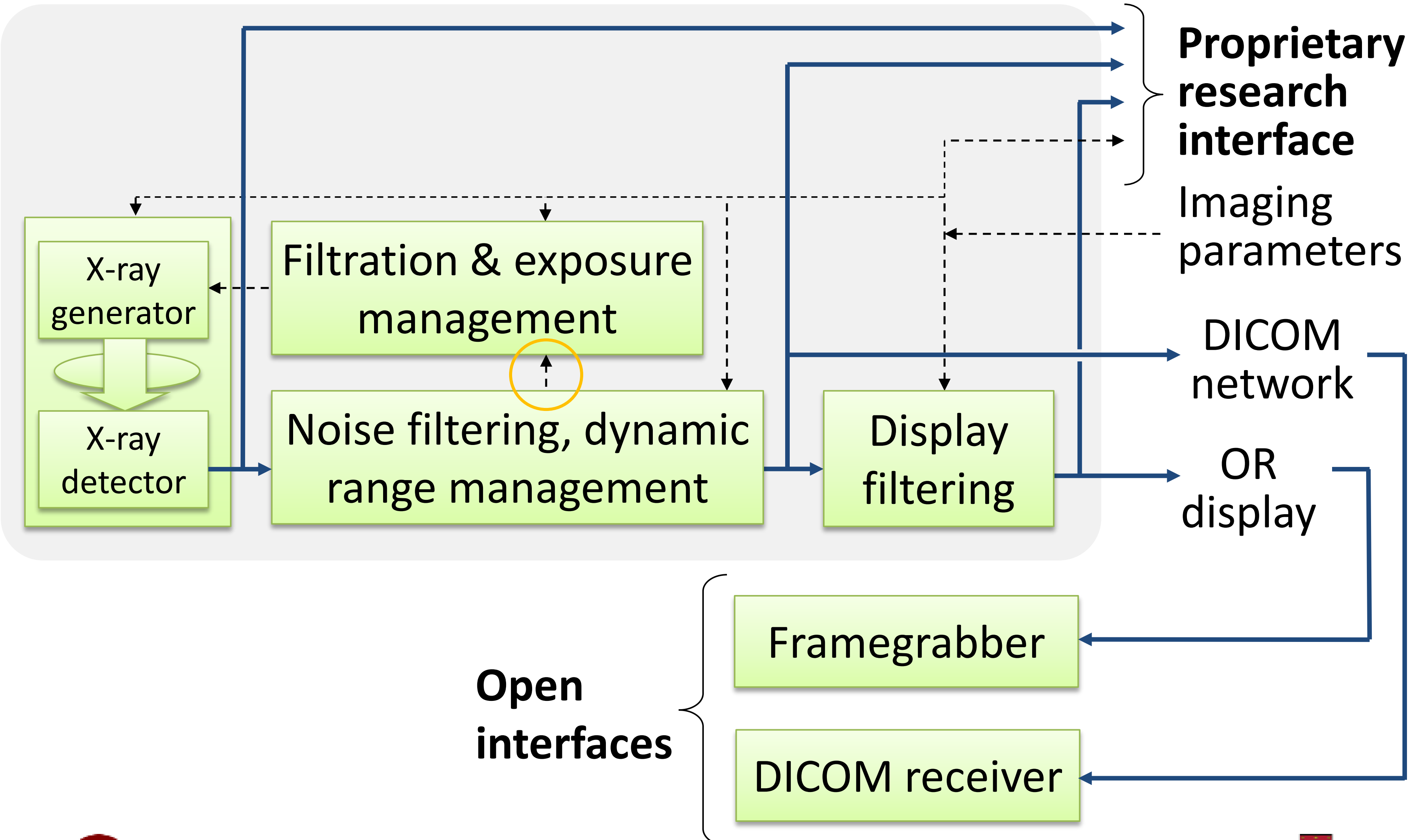


Typical intra-procedural data acquisition and processing workflow

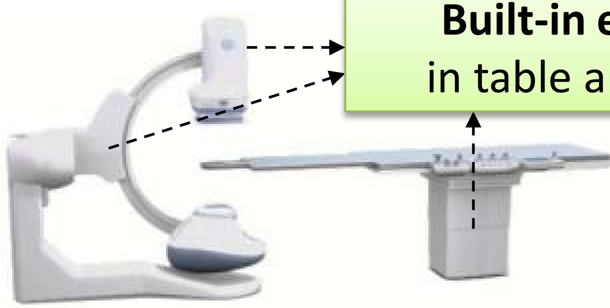
Software and hardware interfaces for data acquisition

	Examples	Administrative workload for getting access	Performance limitations
Open interfaces	Framegrabber, attached external sensor, DICOM	Low	High
Standard research interfaces	OpenIGTLink	Medium	Medium
Proprietary research interfaces	Proprietary hardware and/or software kit from manufacturer	High	Low

Acquisition of X-ray fluoroscopy image data



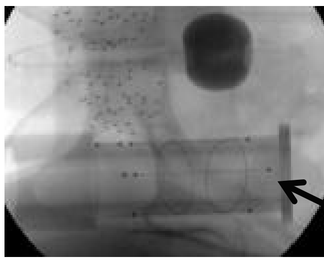
Acquisition X-ray fluoroscopy image pose



Built-in encoders in table and gantry

3 machine angles
Source to image distance
Table position

→ **Proprietary research interface**



Optical pose tracker mounted on table/gantry

Provides full pose,
but line of sight issues

Fiducial in the field of view

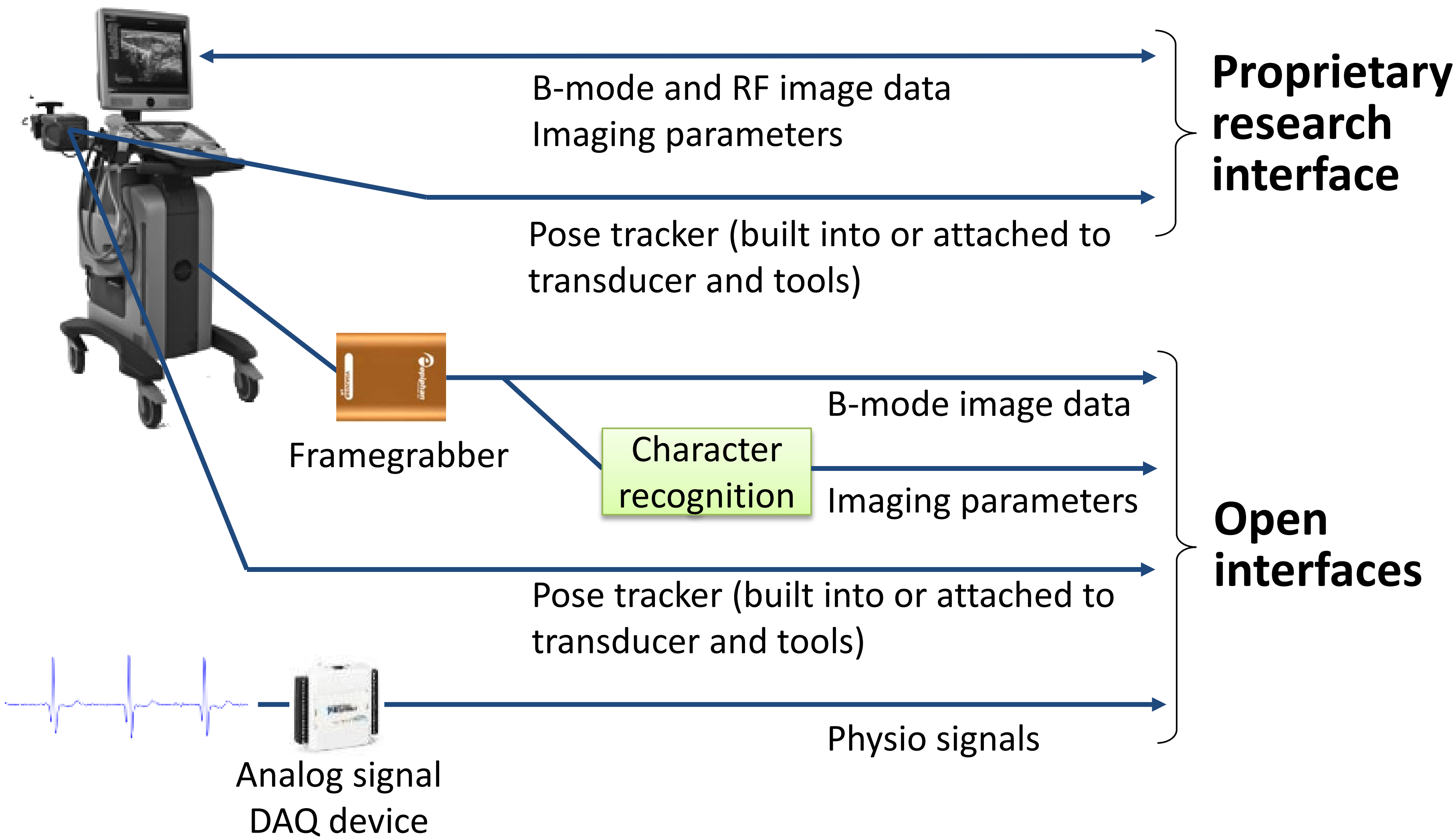
Provides full pose,
but limited operation range

Tilt sensor mounted on gantry

Small, simple, inexpensive,
but orientation only

→ **Open interfaces**

Acquisition of tracked ultrasound images and tool positions



Acquiring images and tracking data using a standard research interface

OpenIGTLink:

- Standard, open interface, developed for image-guided therapy research
- Supports real-time streaming of image, pose, and custom data
- Based on TCP/IP protocol
- Very simple and efficient
- Supported by several device manufacturers and open-source software packages

http://www.na-mic.org/Wiki/index.php/OpenIGTLink

Real-time images
Scan plane pose control

Siemens MRI scanner

OpenIGTLink

Standard research interface

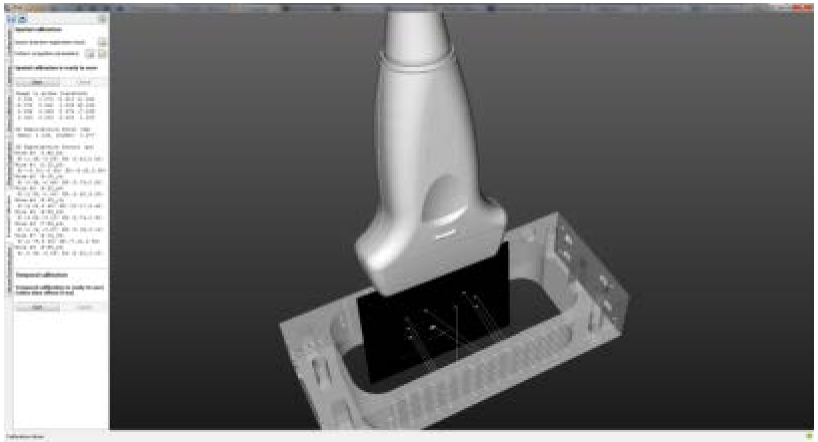
OpenIGTLink

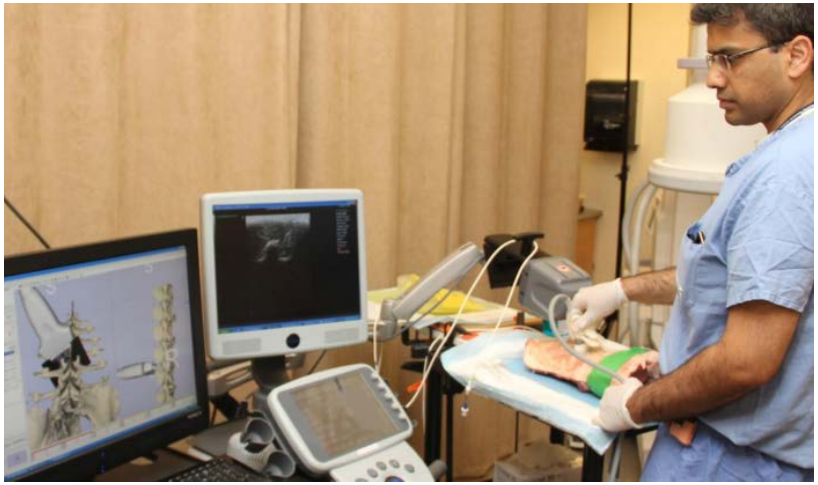
Tool positions
Stored images

BrainLab
pose tracker

PLUS

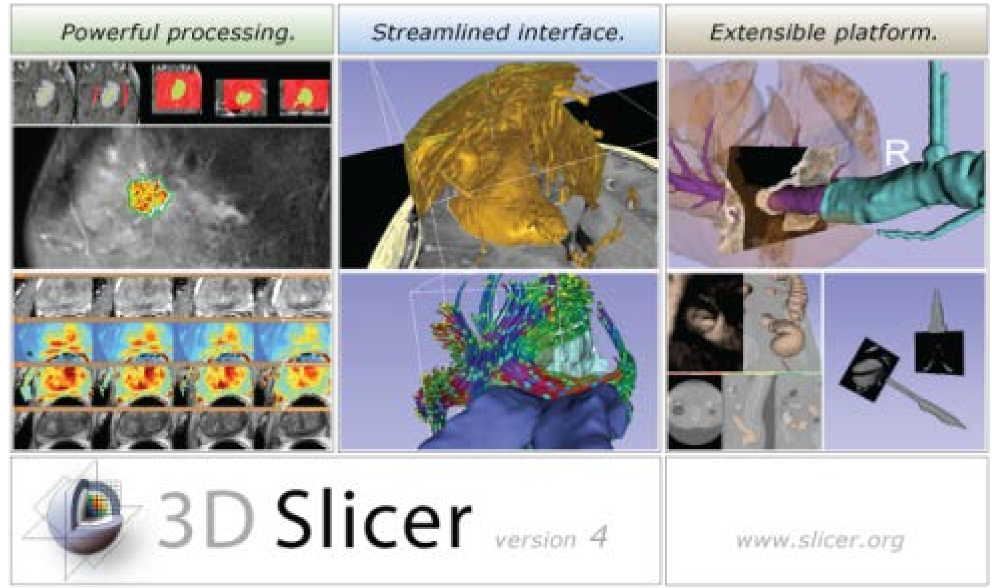
- **P**ublic software **L**ibrary for **U**ltra**s**ound imaging
- Developed at the Laboratory for Percutaneous Surgery
- **Primarily for ultrasound**, but applicable to other imaging modalities
- **Unified interface to a wide variety of imaging and tracking devices**
- **Calibration, data processing, and streaming functionalities**
- Free, BSD license
- Released in Oct 2011, increasing number of users





3D Slicer

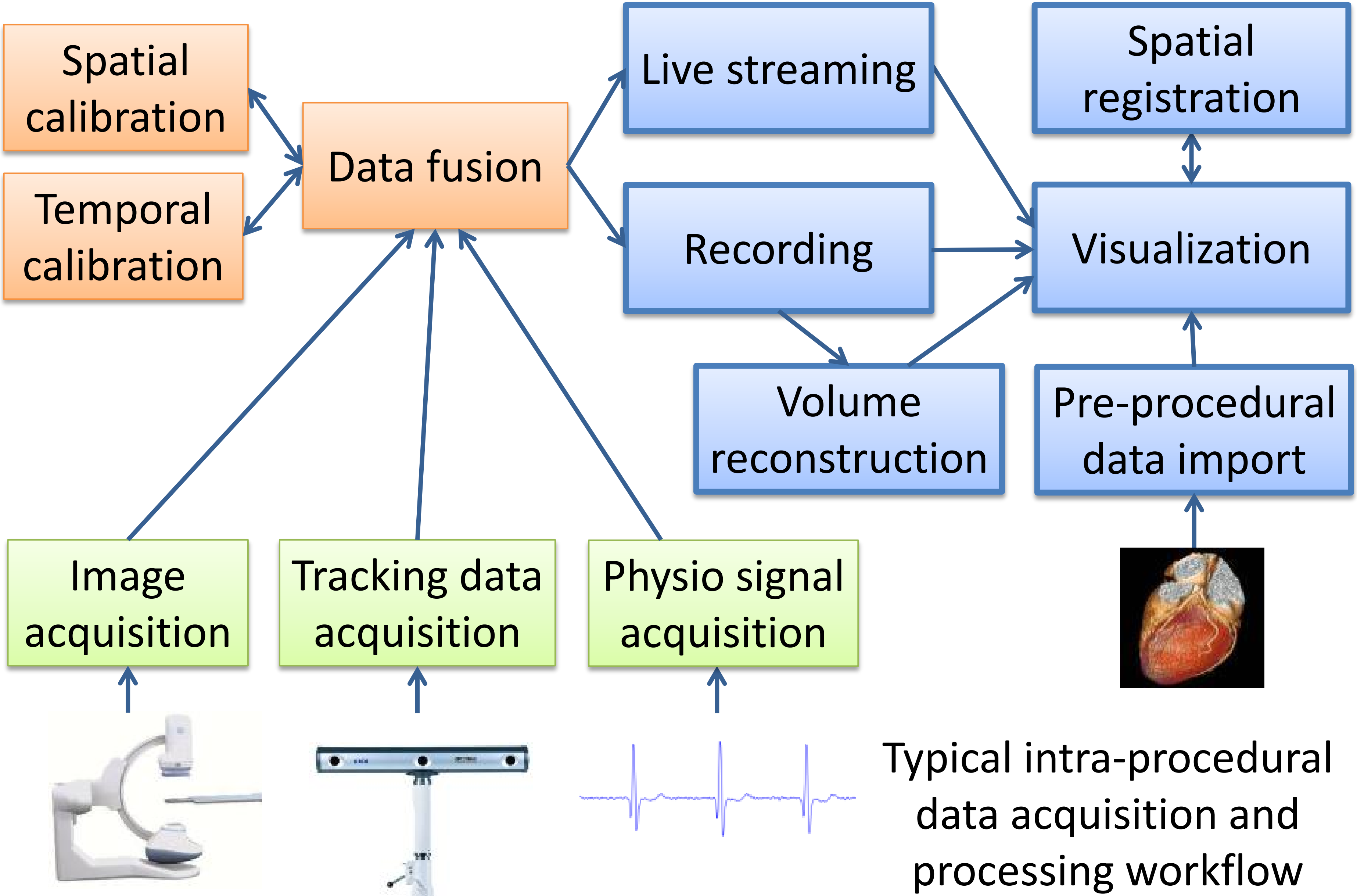
- Medical image visualization and analysis application
- For translational research
- Free, BSD license
- Multi-platform (Windows, Linux, MacOS)
- Uses VTK, ITK, QT, DCMTK



- Generic framework, with plug-ins for specialization
- **Large world-wide developer and user community**
- **User and developer support, extensive testing, training courses, documentation, tutorials**
- **Continuous improvement, now in its 4th generation: some remaining issues, performance optimizations – by Sep. 1, 2012**

Using PLUS and 3D Slicer for data acquisition

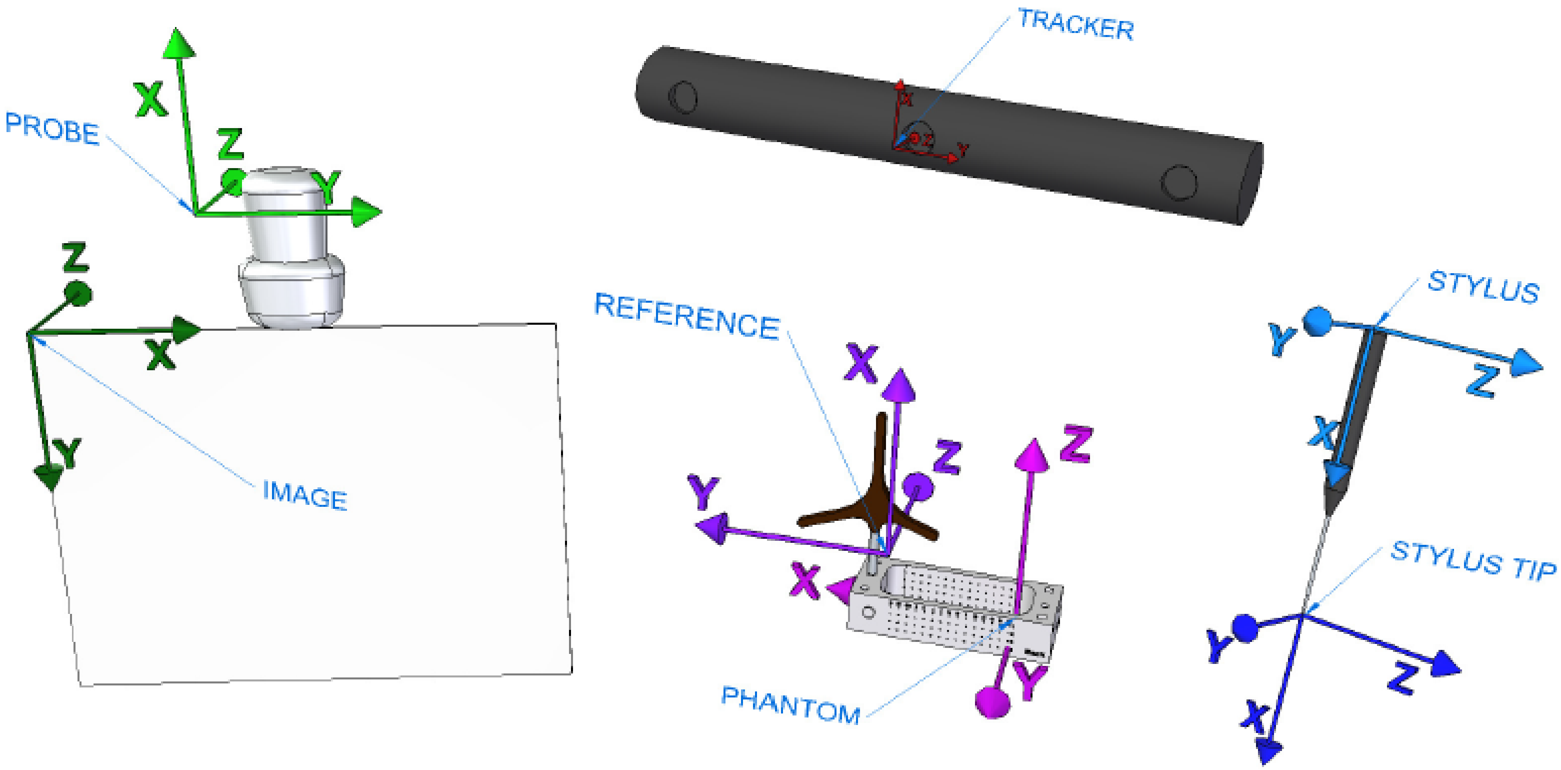
	PLUS toolkit www.assembla.com/spaces/plus	3D Slicer www.slicer.org
Open interfaces	• Framegrabbers (Epiphan, ImagingControls, Video for Windows) • NDI Aurora, Polaris, Certus trackers • Claron MicronTracker • Ascension trakSTAR, medSAFE trackers • Phidget orientation sensor	• DICOM
Standard research interfaces	• OpenIGTLink (send/receive)	• OpenIGTLink (send/receive)
Proprietary research interfaces	• Ultrasonix ultrasound scanners (Ulterius and Porta SDK) • BK Medical ultrasound scanners	



Typical intra-procedural data acquisition and processing workflow

Spatial calibration

Goal: determine pose of images and tools relative to tracked markers

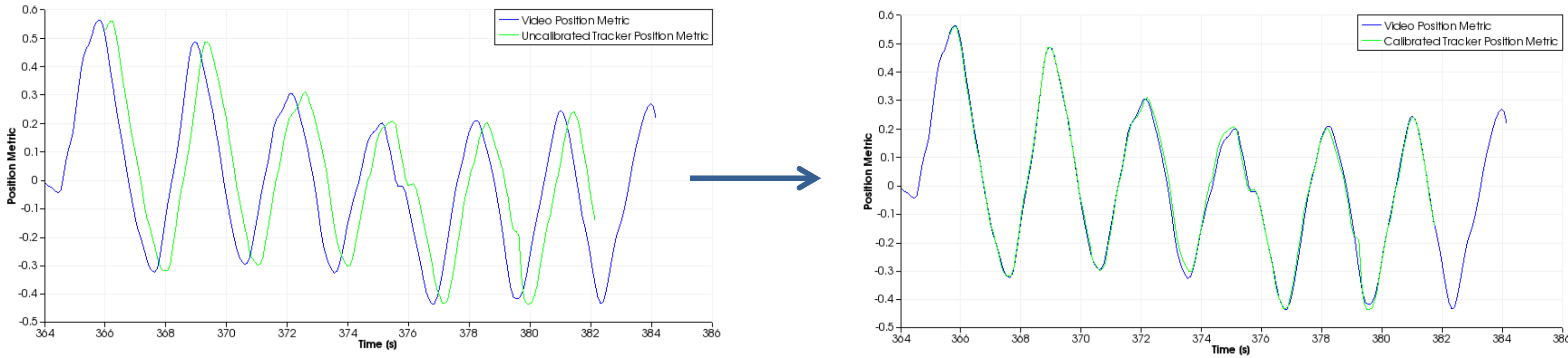


Spatial calibration methods

	Inputs	Result
Pivot calibration	• Pose of tracked marker attached to a tool	Tooltip position relative to tracked marker
Landmark registration	• Point positions from the tracking system • Point positions in the tool model	Tool pose relative to tracked marker
Z-frame-based image registration	• Pose of tracked marker attached to imaging device • Images produced by the device • Z fiducial positions in the tool model	Image pose relative to tracked marker
Intensity-based image registration	• Two images showing the same object in different coordinate systems	Relative pose of the coordinate systems
Manual registration	• Images and/or surface models of the same object in different coordinate systems • User input for aligning the objects	Relative pose of the coordinate systems

Temporal calibration

- Goal: determine time offset between data streams
- Extract the same information (e.g., position) and find the time offset that leads to maximum correlation of the signals

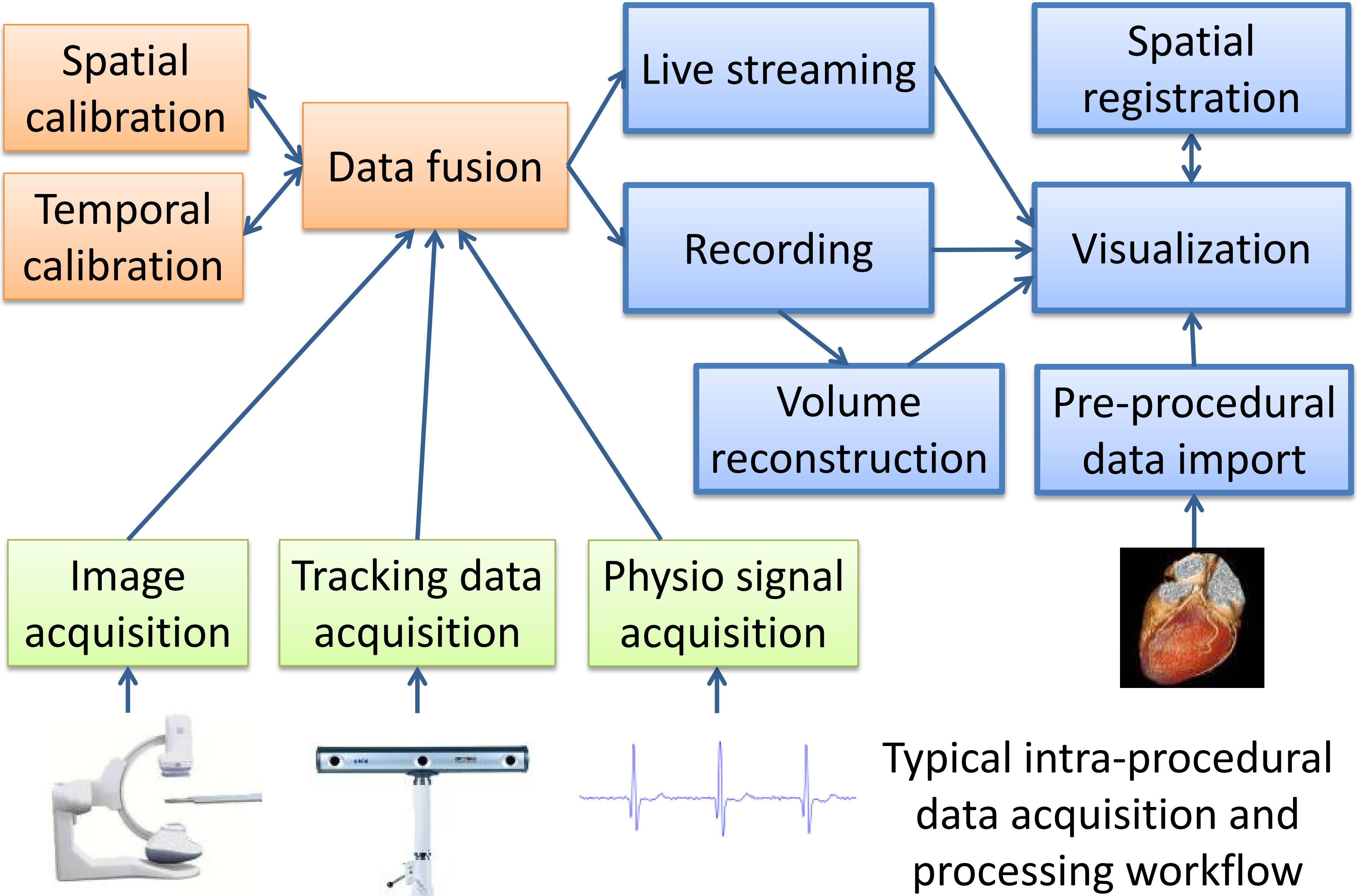


- Use accurate clock (usually ~1ms is achievable)
- Timestamp filtering: detect delayed data, reduce jitter
- Limit maximum speed

Using PLUS and 3D Slicer for system calibration

	PLUS toolkit www.assembla.com/spaces/plus	3D Slicer www.slicer.org
Spatial calibration	• Pivot calibration • Landmark registration • Z-frame-based image registration	• Landmark registration • Intensity-based image registration • Manual registration
Temporal calibration	• Correlation-based temporal calibration of ultrasound image and pose	

All these features are readily usable without the need for any additional software development.



Typical intra-procedural data acquisition and processing workflow

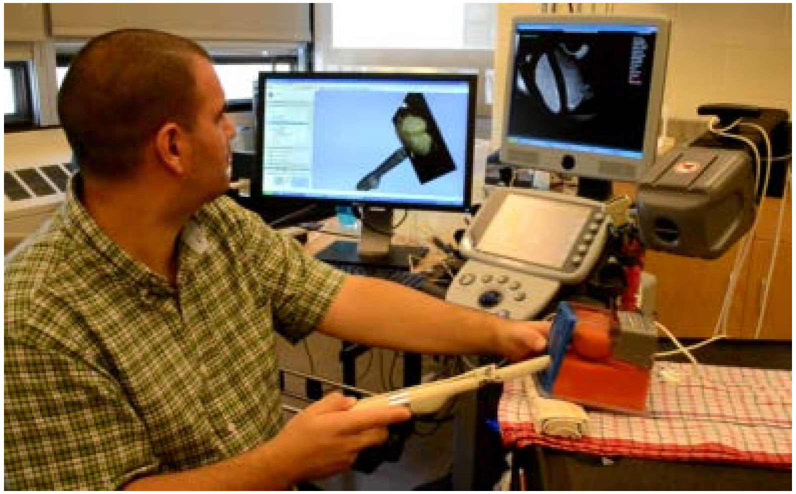
Using PLUS and 3D Slicer for basic visualization and processing

	PLUS toolkit www.assembla.com/spaces/plus	3D Slicer www.slicer.org
Processing	• Data recording • Volume reconstruction from slices	• Segmentation • Registration • Measurements • … many more
Visualization		• 2D/3D visualization: slice, surface, volume rendering • Image fusion • Real-time image and tool display • … many more

All these features are readily usable without the need for any additional software development.

Summary

- Use standard research interfaces (OpenIGTLink)
- Use free open-source tools
  - Conversion from proprietary interface to unified, standard interfaces
  - System calibration
  - Visualization and processing



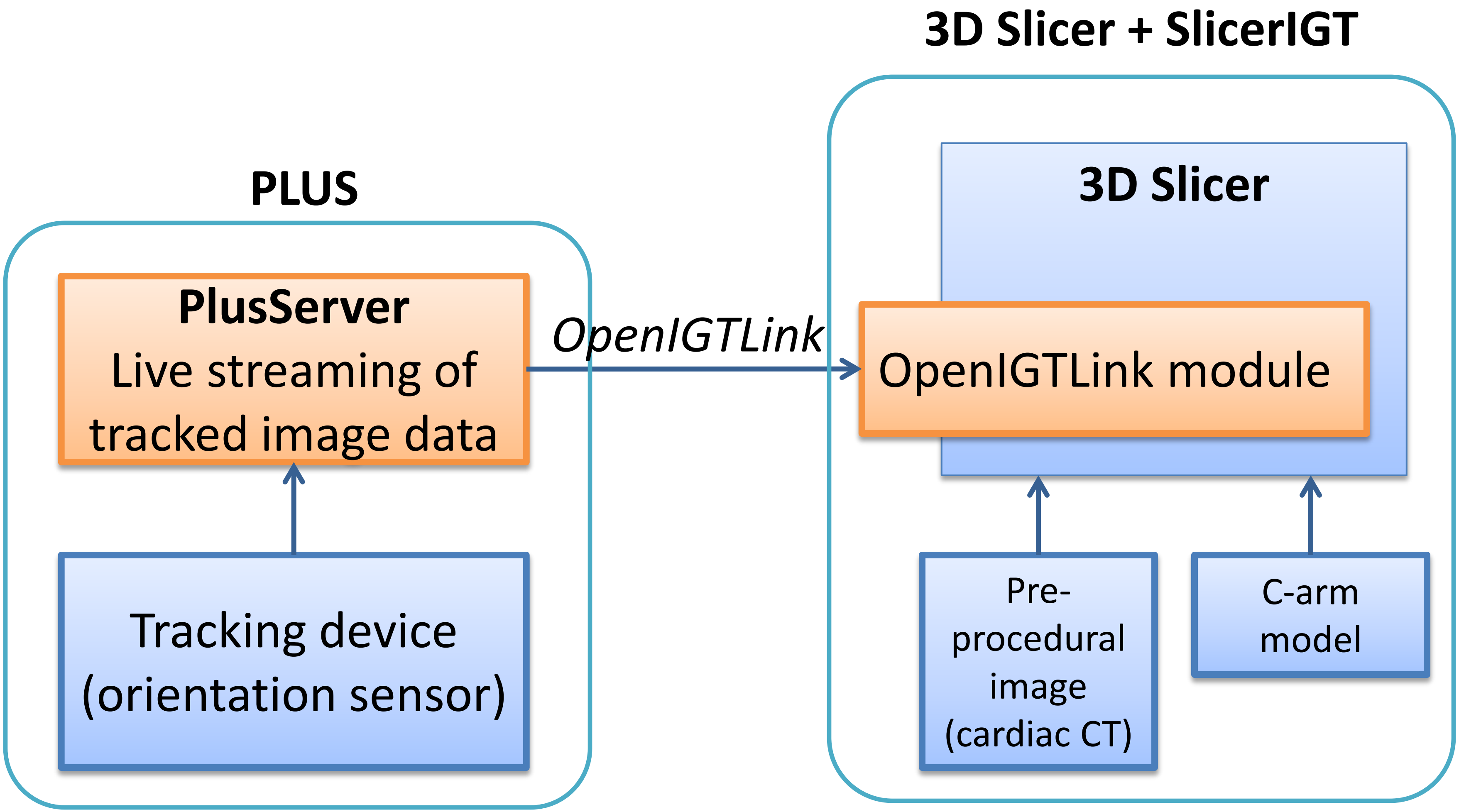
PLUS: www.assembla.com/spaces/plus

SlicerIGT: www.assembla.com/spaces/slicerigt

3D Slicer: www.slicer.org

Andras Lasso (lasso@cs.queensu.ca)

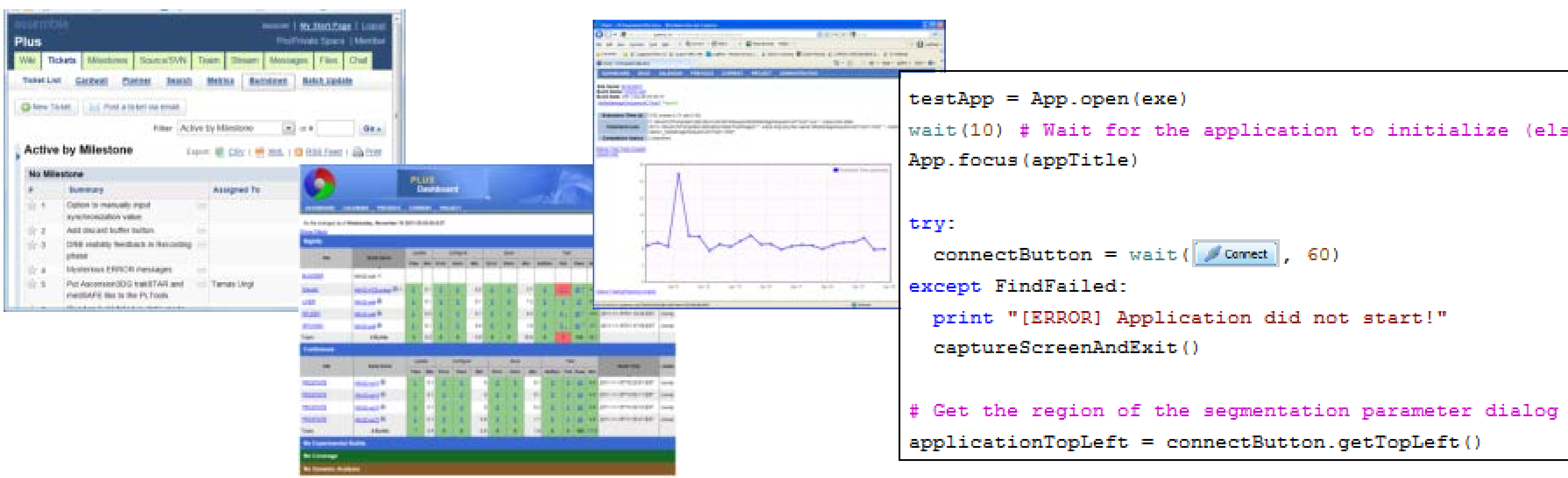
Demonstration



Appendix

Software process

- Source control, tickets, releases, messaging (www.assembla.com/spaces/plus)
- Standardized build environment (CMake automatically downloads and configures all required software components
- Documentation: wiki, doxygen
- Automatic tests: CTest, CDash, Sikuli



Spatial calibration

Tutorials with all data, models, tricks

- [Performing tracked ultrasound probe calibration using fCal]
- [How to build an fCal calibration phantom]

Sequence metafile (.mha)

- Extension to the *Meta IO* standard file format
- Slices readable by many existing applications
- Extra information for tracking/reconstruction
  - Frame number
  - Unfiltered and filtered timestamp
  - Probe and Reference tracking transforms
  - …
- Used by all applications of Plus