Real-Time Data Acquisition for Cardiovascular Research

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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

<table>
<thead>
<tr>
<th>Open interfaces</th>
<th>Examples</th>
<th>Administrative workload for getting access</th>
<th>Performance limitations</th>
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<tbody>
<tr>
<td>Framegrabber, attached external sensor, DICOM</td>
<td>Low</td>
<td>High</td>
<td></td>
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<th>Standard research interfaces</th>
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<tr>
<td>OpenIGTLink</td>
<td>Medium</td>
<td>Medium</td>
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<tr>
<th>Proprietary research interfaces</th>
<th>Examples</th>
<th>Administrative workload for getting access</th>
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<tr>
<td>Proprietary hardware and/or software kit from manufacturer</td>
<td>High</td>
<td>Low</td>
<td></td>
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</table>
Acquisition of X-ray fluoroscopy image data

X-ray generator

X-ray detector

Filtration & exposure management

Noise filtering, dynamic range management

Display filtering

DICOM network

OR display

Proprietary research interface

Imaging parameters

Open interfaces

Framegrabber

DICOM receiver

DICOM network
Acquisition X-ray fluoroscopy image pose

Proprietary research interface

Built-in encoders in table and gantry
- 3 machine angles
- Source to image distance
- Table position

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

Open interfaces

Tilt sensor mounted on gantry
- Small, simple, inexpensive, but orientation only
Acquisition of tracked ultrasound images and tool positions

- B-mode and RF image data
- Imaging parameters
- Pose tracker (built into or attached to transducer and tools)
- Framegrabber
- Character recognition
- B-mode image data
- Imaging parameters
- Pose tracker (built into or attached to transducer and tools)
- Analog signal
- DAQ device
- Physio signals

Proprietary research interface

Open interfaces
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
PLUS

• **Public software Library for Ultrasound 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

<table>
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<tr>
<th>Open interfaces</th>
<th>PLUS toolkit</th>
<th>3D Slicer</th>
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</thead>
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<tr>
<td>Framegrabbers</td>
<td>• Framegrabbers (Epiphan, ImagingControls, Video for Windows)</td>
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<tr>
<td></td>
<td>• NDI Aurora, Polaris, Certus trackers</td>
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<tr>
<td></td>
<td>• Claron MicronTracker</td>
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<td></td>
<td>• Ascension trakSTAR, medSAFE trackers</td>
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<tr>
<td></td>
<td>• Phidget orientation sensor</td>
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<tr>
<td>Standard research interfaces</td>
<td>• OpenIGTLink (send/receive)</td>
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<tr>
<td>Proprietary research interfaces</td>
<td>• Ultrasonix ultrasound scanners (Ulterius and Porta SDK)</td>
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<tr>
<td></td>
<td>• BK Medical ultrasound scanners</td>
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Typical intra-procedural data acquisition and processing workflow
Spatial calibration

Goal: determine pose of images and tools relative to tracked markers
## Spatial calibration methods

<table>
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<tr>
<th>Method</th>
<th>Inputs</th>
<th>Result</th>
</tr>
</thead>
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<tr>
<td>Pivot calibration</td>
<td>• Pose of tracked marker attached to a tool</td>
<td>Tooltip position relative to tracked marker</td>
</tr>
<tr>
<td>Landmark registration</td>
<td>• Point positions from the tracking system</td>
<td>Tool pose relative to tracked marker</td>
</tr>
<tr>
<td></td>
<td>• Point positions in the tool model</td>
<td></td>
</tr>
<tr>
<td>Z-frame-based image registration</td>
<td>• Pose of tracked marker attached to imaging device</td>
<td>Image pose relative to tracked marker</td>
</tr>
<tr>
<td></td>
<td>• Images produced by the device</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Z fiducial positions in the tool model</td>
<td></td>
</tr>
<tr>
<td>Intensity-based image registration</td>
<td>• Two images showing the same object in different coordinate systems</td>
<td>Relative pose of the coordinate systems</td>
</tr>
<tr>
<td>Manual registration</td>
<td>• Images and/or surface models of the same object in different coordinate systems</td>
<td>Relative pose of the coordinate systems</td>
</tr>
<tr>
<td></td>
<td>• User input for aligning the objects</td>
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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 \( \sim 1\text{ms} \) is achievable)
  - Timestamp filtering: detect delayed data, reduce jitter
  - Limit maximum speed
Using PLUS and 3D Slicer for system calibration

<table>
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<th>Spatial calibration</th>
<th>PLUS toolkit</th>
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<td>• Intensity-based image registration</td>
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<tr>
<td>• Z-frame-based image registration</td>
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<td>• Manual registration</td>
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<th>Temporal calibration</th>
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<tbody>
<tr>
<td>• Correlation-based temporal calibration of ultrasound image and pose</td>
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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

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<tr>
<td><strong>Processing</strong></td>
<td>• Data recording</td>
<td>• Segmentation</td>
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<td></td>
<td>• Volume reconstruction from slices</td>
<td>• Registration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Measurements</td>
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<td></td>
<td></td>
<td>• ... many more</td>
</tr>
<tr>
<td><strong>Visualization</strong></td>
<td></td>
<td>• 2D/3D visualization: slice, surface, volume rendering</td>
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<td>• Image fusion</td>
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<td></td>
<td></td>
<td>• Real-time image and tool display</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ... many more</td>
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</tbody>
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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

PLUS

PlusServer
Live streaming of tracked image data

Tracking device (orientation sensor)

3D Slicer + SlicerIGT

3D Slicer

OpenIGTLink module

Pre-procedural image (cardiac CT)

C-arm model

OpenIGTLink
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