SlicerROS2: ROS for Medical Robots

Hamlyn Symposium on Medical Robotics

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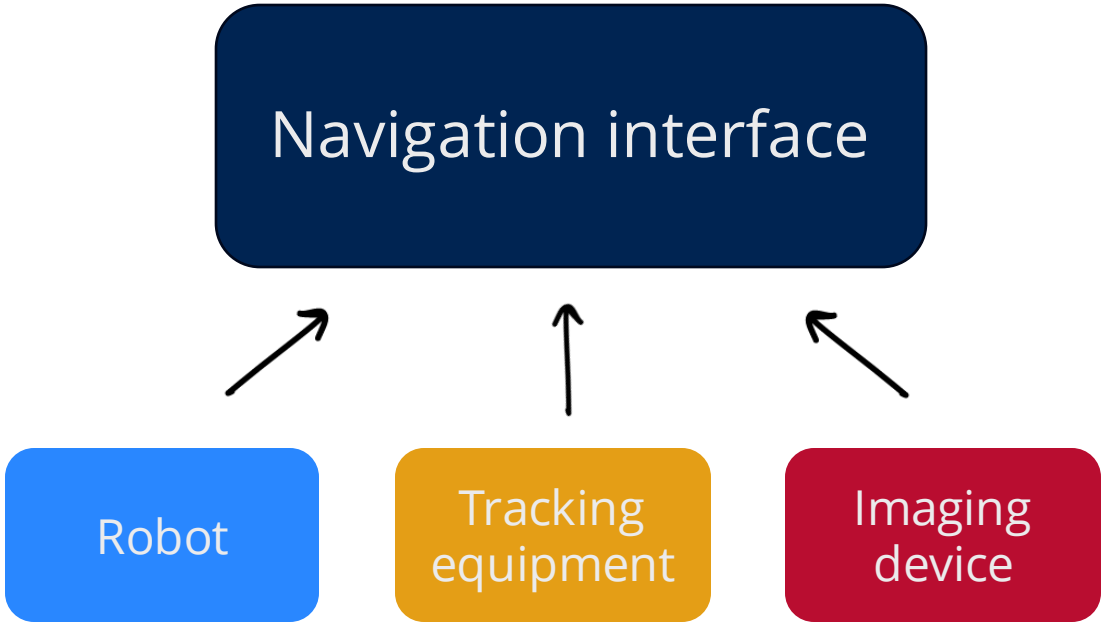
Advisors and developers on SlicerROS2: Professor Simon Leonard & Anton Deguet & Aravind S. Kumar

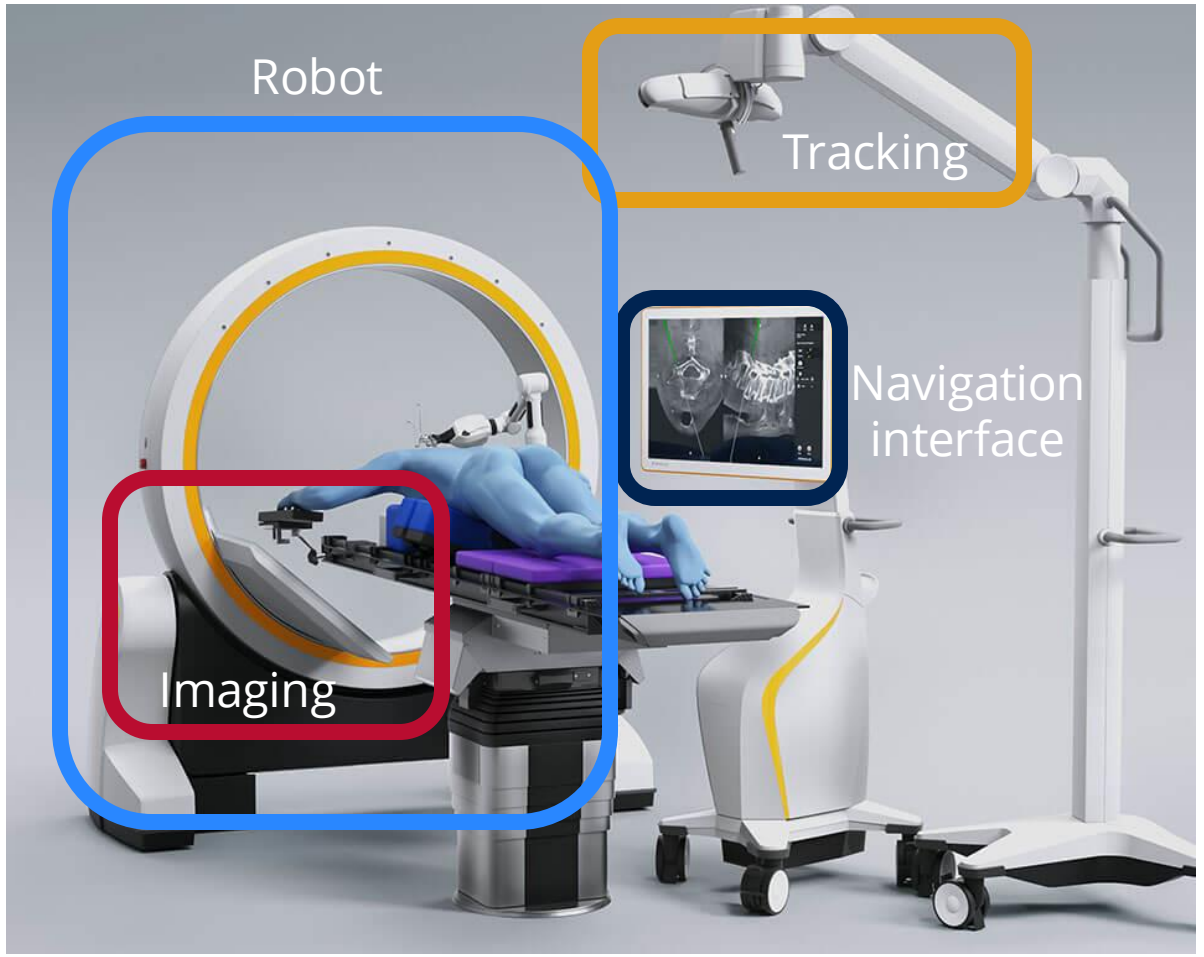
Background

Image-guided robotic interventions are medical procedures that integrate sophisticated robotic and imaging technologies, primarily to perform minimally invasive surgery [1]

[1] https://www.nibib.nih.gov/science-education/science-topics/image-guided-robotic-interventions
Photo credit: https://www.intuitive.com/en-us

Building robotic IGT systems





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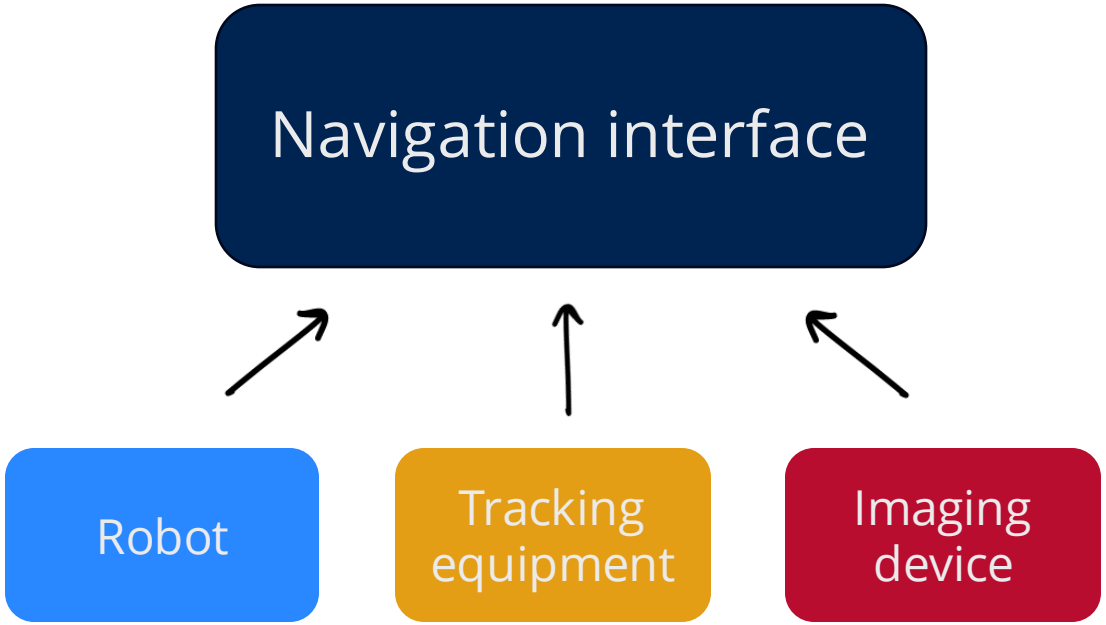
Building robotic IGT systems



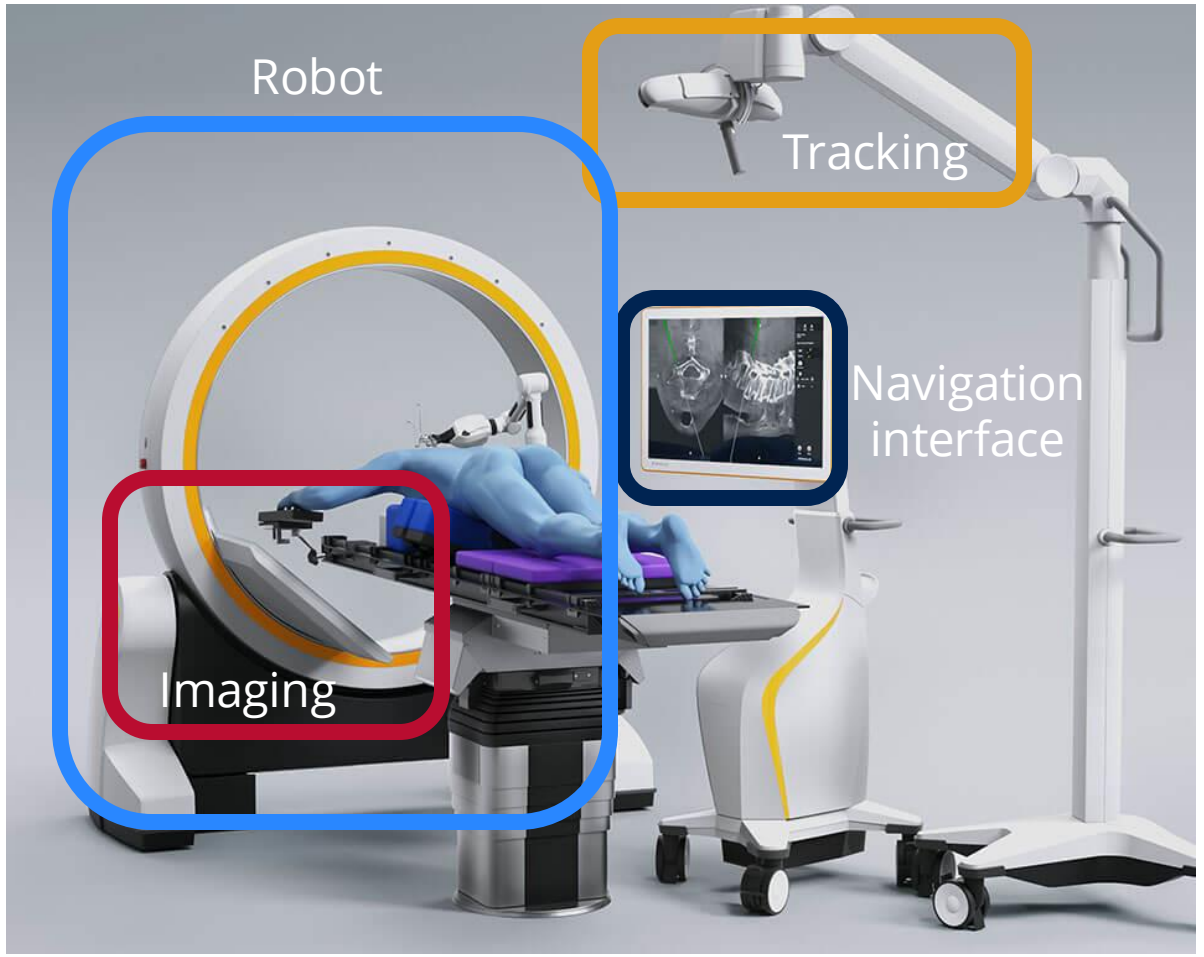
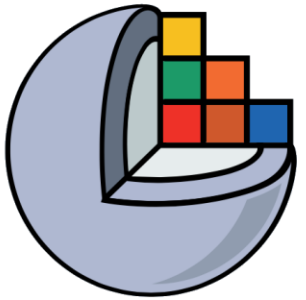
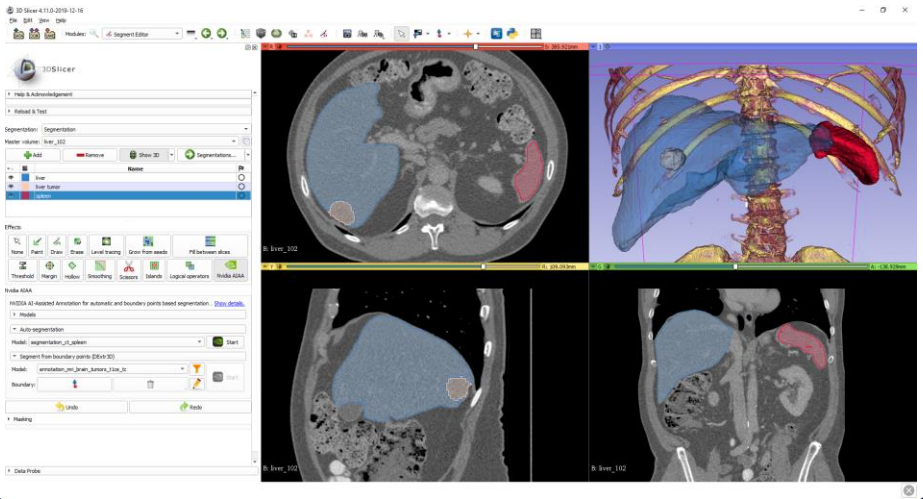


Photo credit: www.brainlab.com

3D Slicer

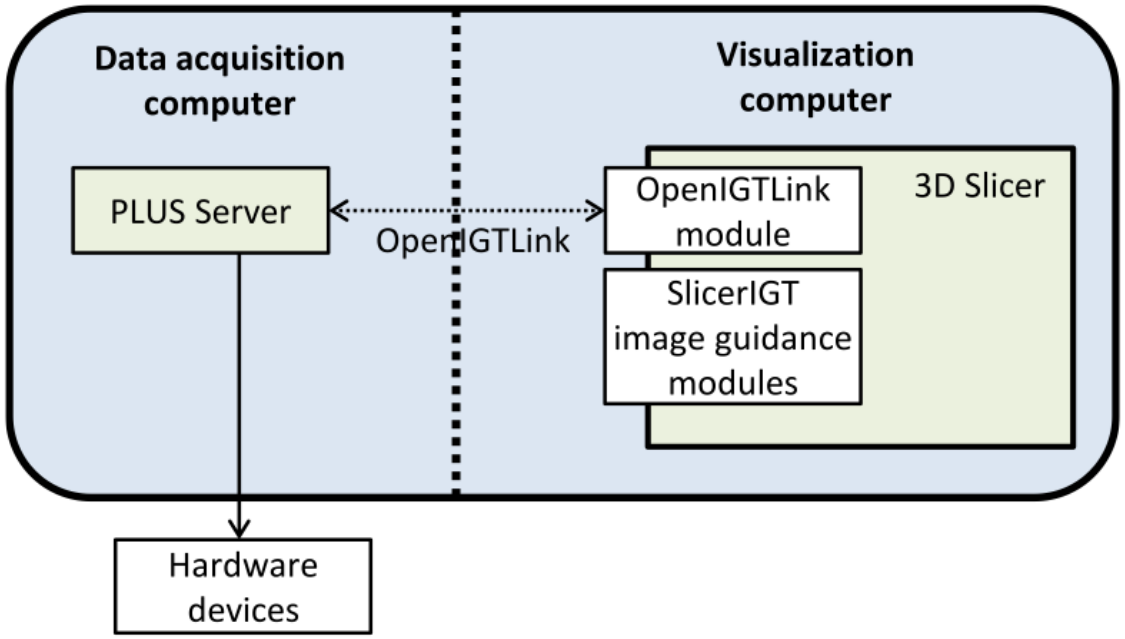
- Open source, medical imaging platform (over 1 million downloads in the past 10 years)
- Several built-in extensions
- Can be used for:
    1. Segmentation
    2. Image analysis
    3. Surgical navigation
    4. Tracked imaging
    5. Adaptive radiation therapy
    6. Volume reconstruction
    7. Virtual and Augmented Reality
    8. ....





PLUS toolkit

- Software toolkit for data acquisition, pre-processing, and calibration for navigated image-guided interventions

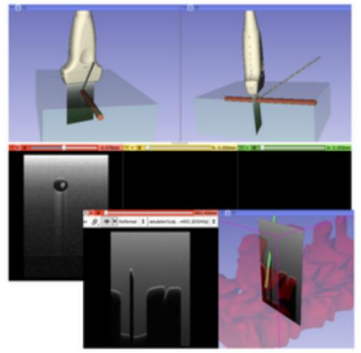


Highlights

Position data acquisition from various devices, including electromagnetic trackers (Ascension, NDI Aurora) and optical trackers (OptiTrack, NDI Polaris and Certus, Claron MicronTracker)

Data acquisition from commercial surgical navigation systems: Medtronic StealthStation navigation system (receives tracking data and planning volume), BrainLab navigation system (receives tracking data, planning volume, and landmarks; through OpenIGTLink)

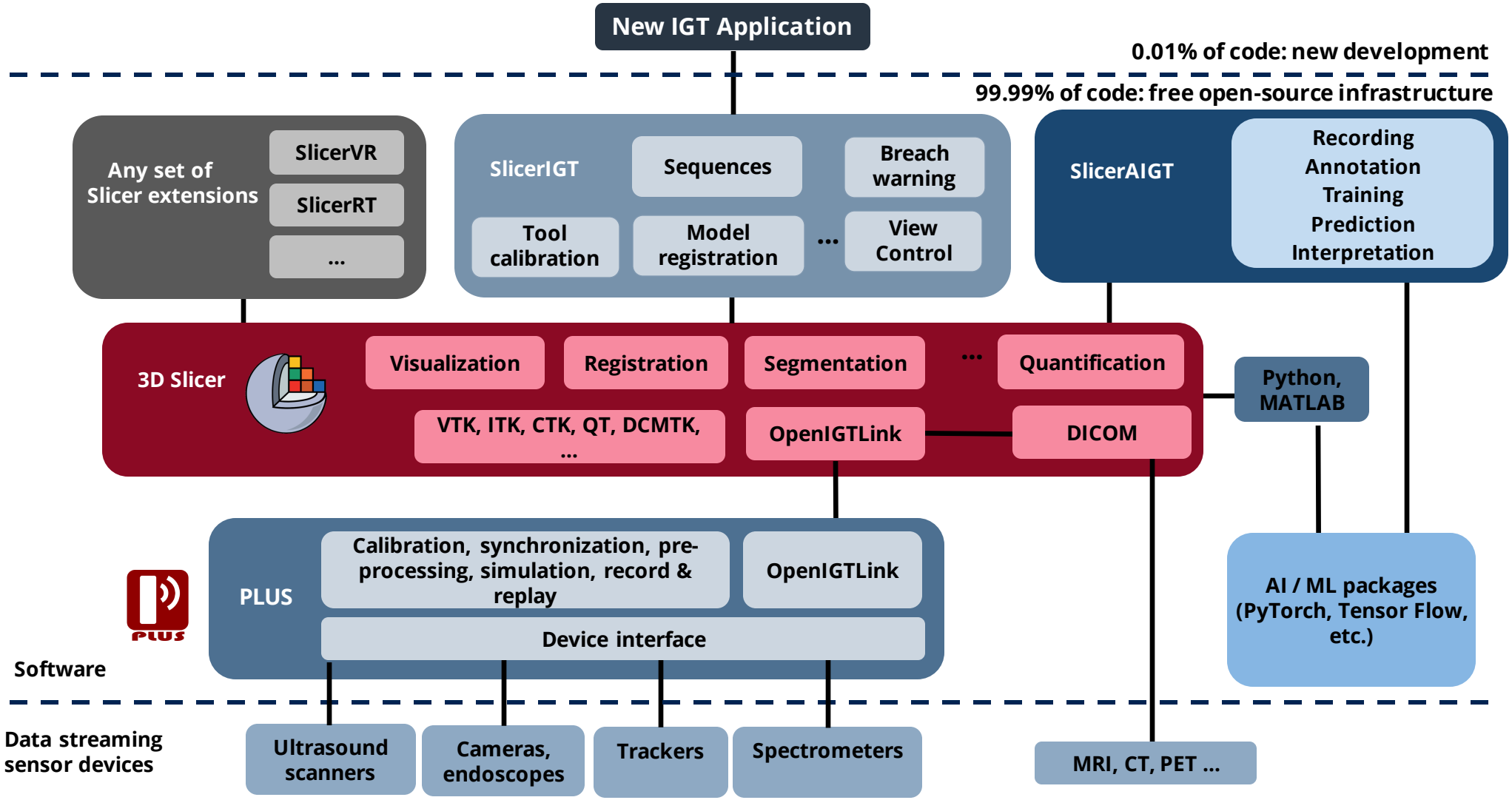
Image acquisition from ultrasound systems: through direct digital interface (for Ultrasonix, BK, Interson, Telemed, Philips ultrasound scanners) and through framegrabbers



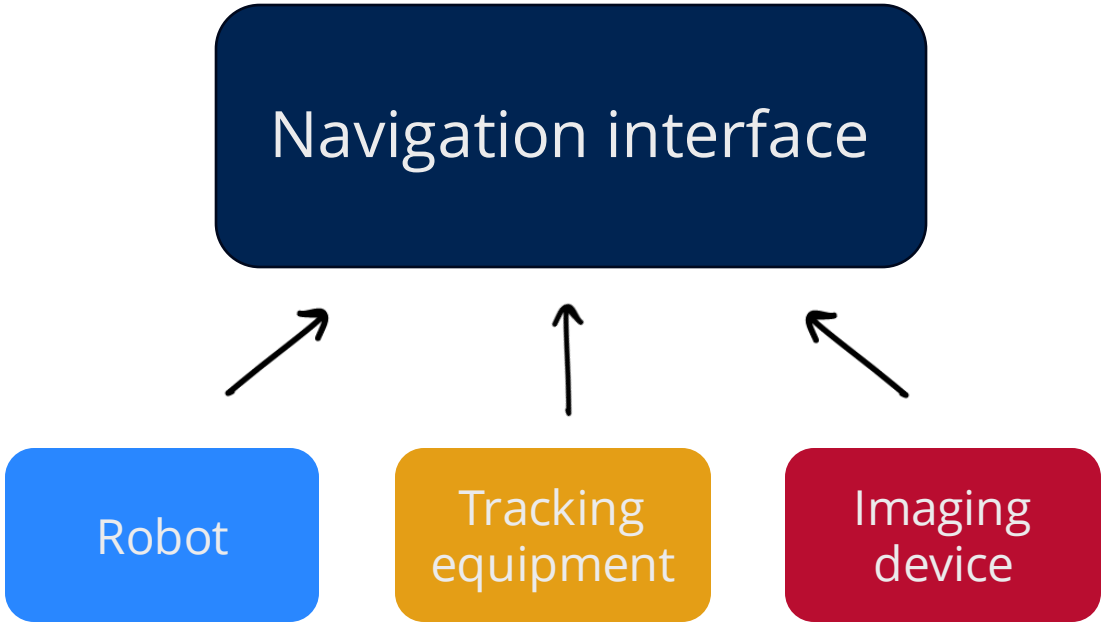
Ultrasound image simulation: B-mode images are generated from multiple moving objects (such as bones, soft tissue, tools), each defined by a simple surface mesh.

Lasso, Andras, et al. "PLUS: open-source toolkit for ultrasound-guided intervention systems." *IEEE transactions on biomedical engineering* 61.10 (2014): 2527-2537.

SlicerIGT


New IGT Application
0.01% of code: new development
99.99% of code: free open-source infrastructure
Any set of Slicer extensions
SlicerVR
SlicerRT
...
SlicerIGT
Sequences
Breach warning
Tool calibration
Model registration
...
View Control
SlicerAIGT
Recording
Annotation
Training
Prediction
Interpretation
3D Slicer
Visualization
Registration
Segmentation
...
Quantification
VTK, ITK, CTK, QT, DCMTK, ...
OpenIGTLink
DICOM
Python, MATLAB
PLUS
Calibration, synchronization, pre-processing, simulation, record & replay
OpenIGTLink
Device interface
AI / ML packages (PyTorch, Tensor Flow, etc.)
Software
Data streaming sensor devices
Ultrasound scanners
Cameras, endoscopes
Trackers
Spectrometers
MRI, CT, PET ...

Building robotic IGT systems



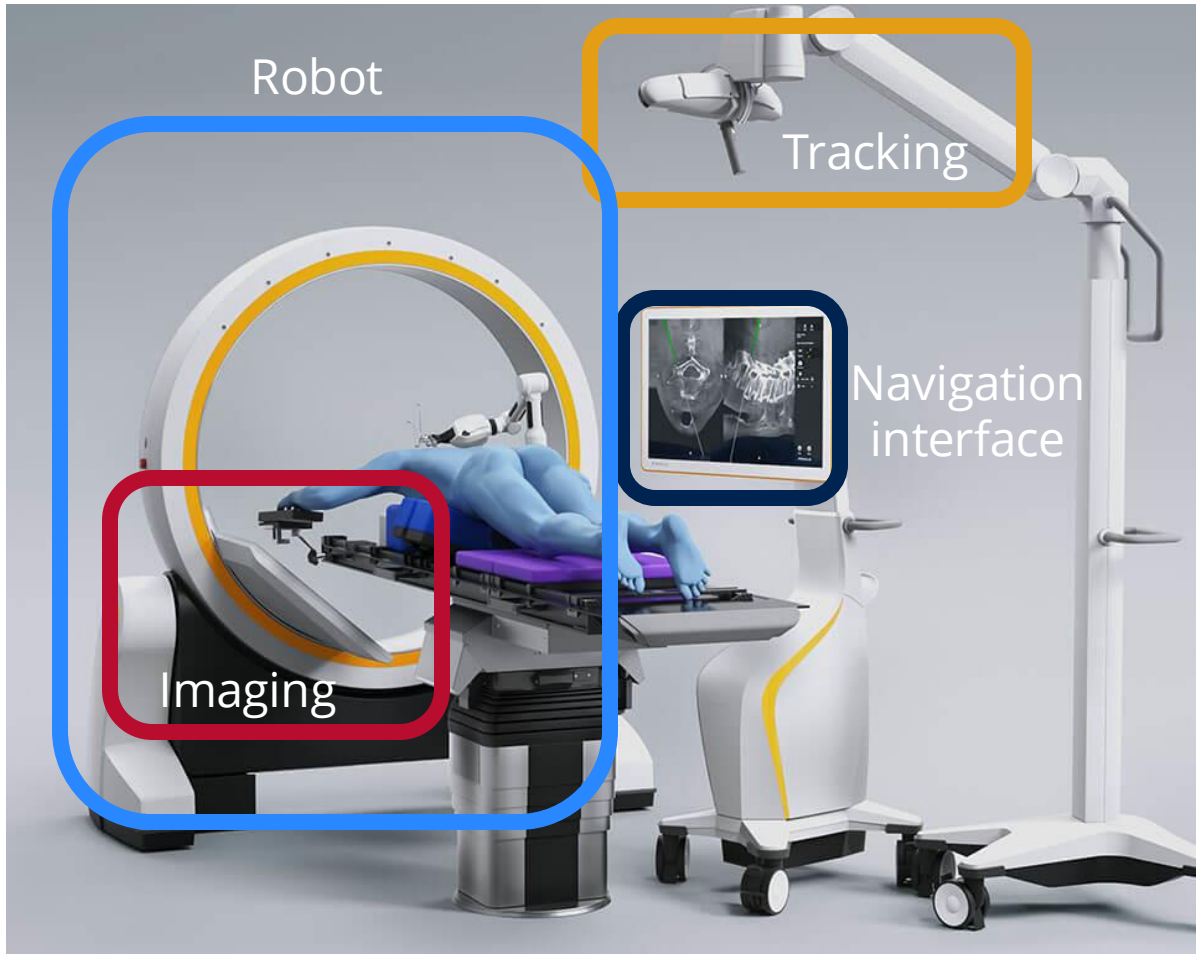
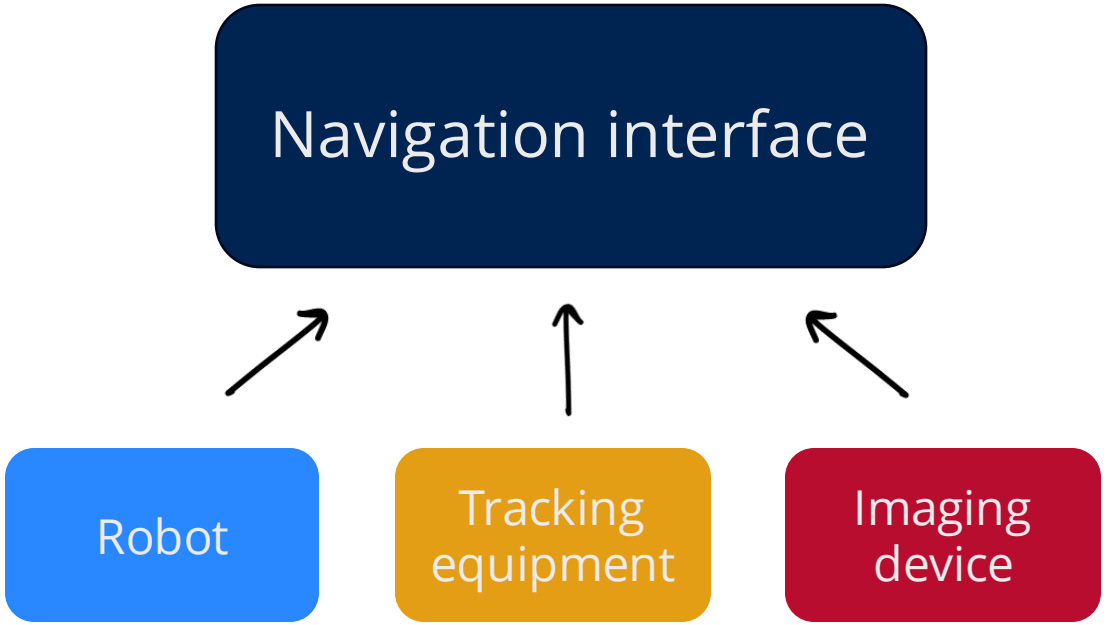


Photo credit: www.brainlab.com

Building robotic IGT systems



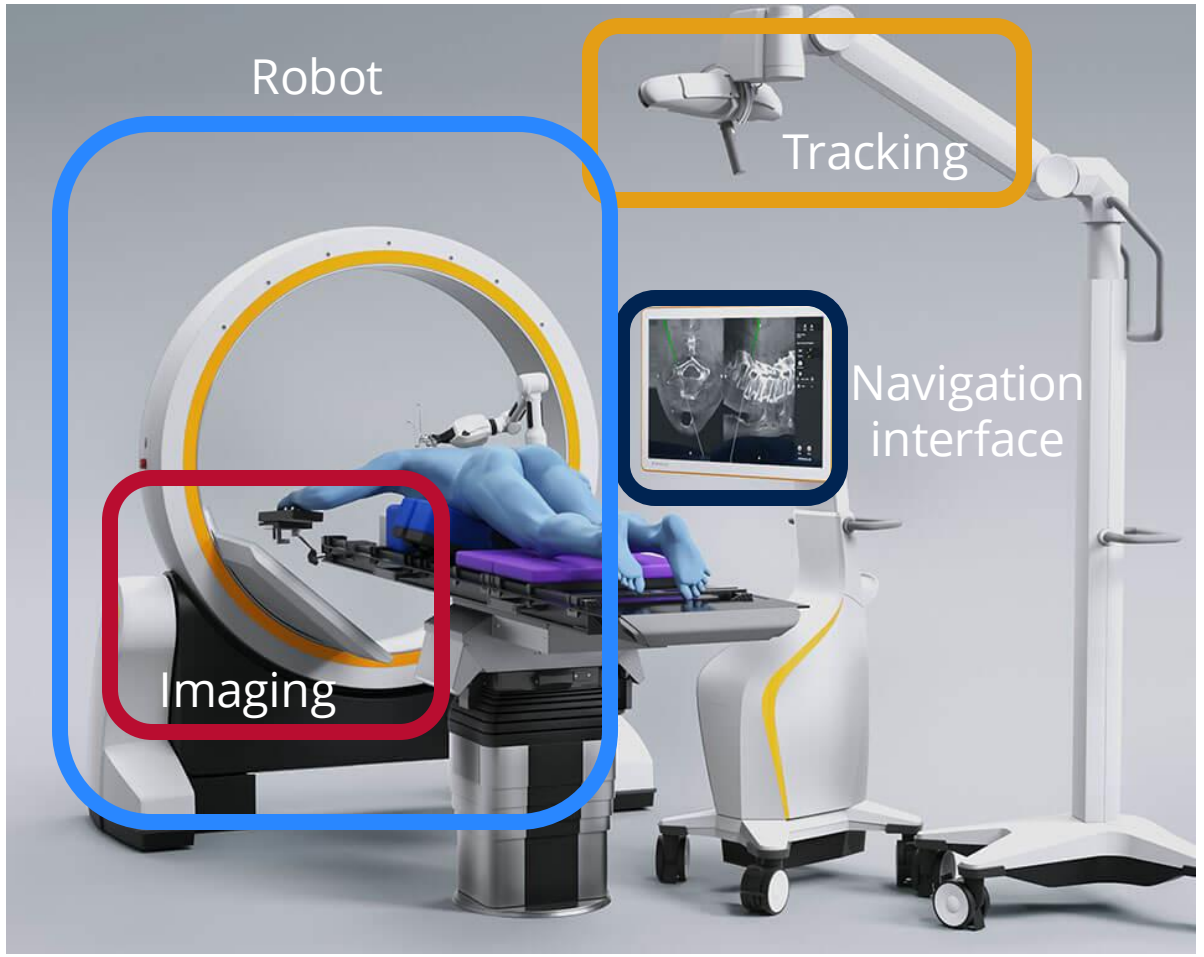
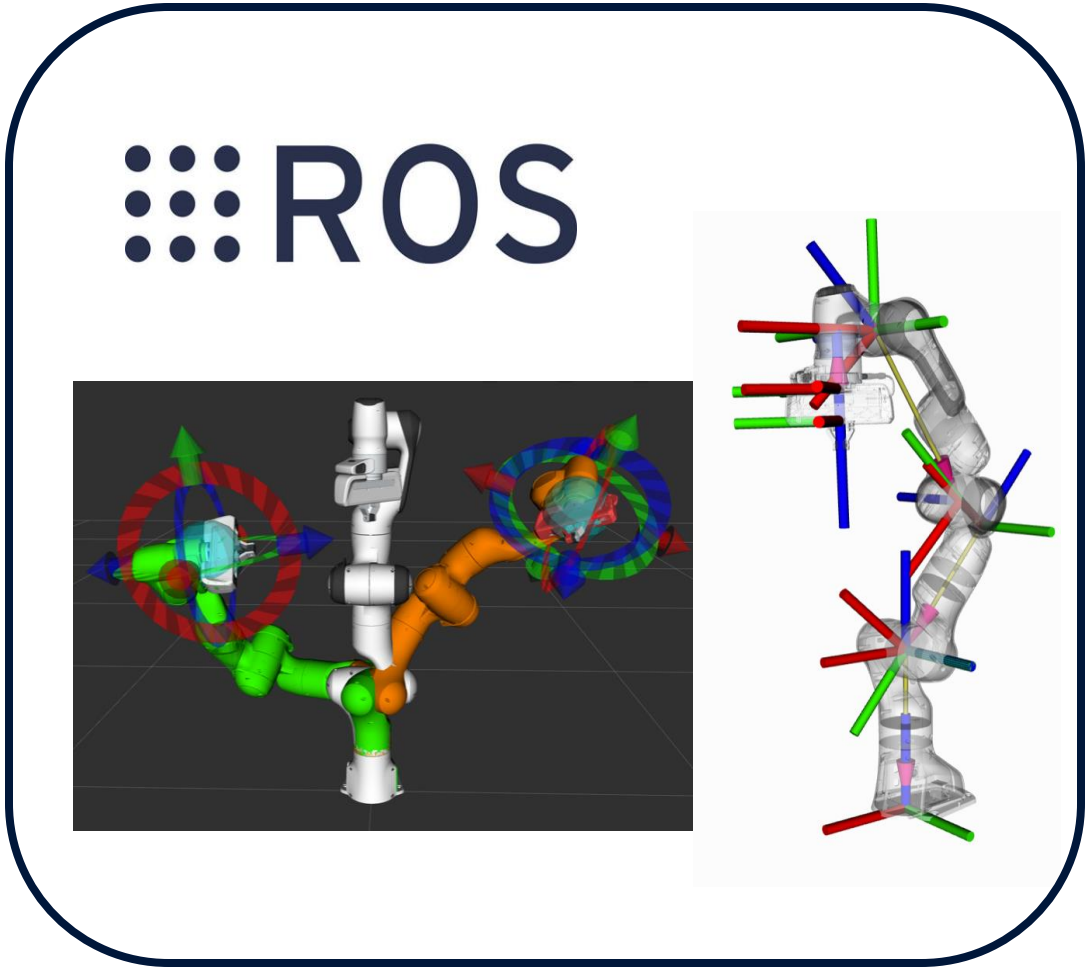


Photo credit: www.brainlab.com

Robot operating system (ROS)

- ROS is a set of libraries that make it easier to develop robot applications
- Examples:
  - Inverse kinematics solvers already implemented
  - MoveIt – package that does motion planning
  - tf - maintains the transformation chain between links

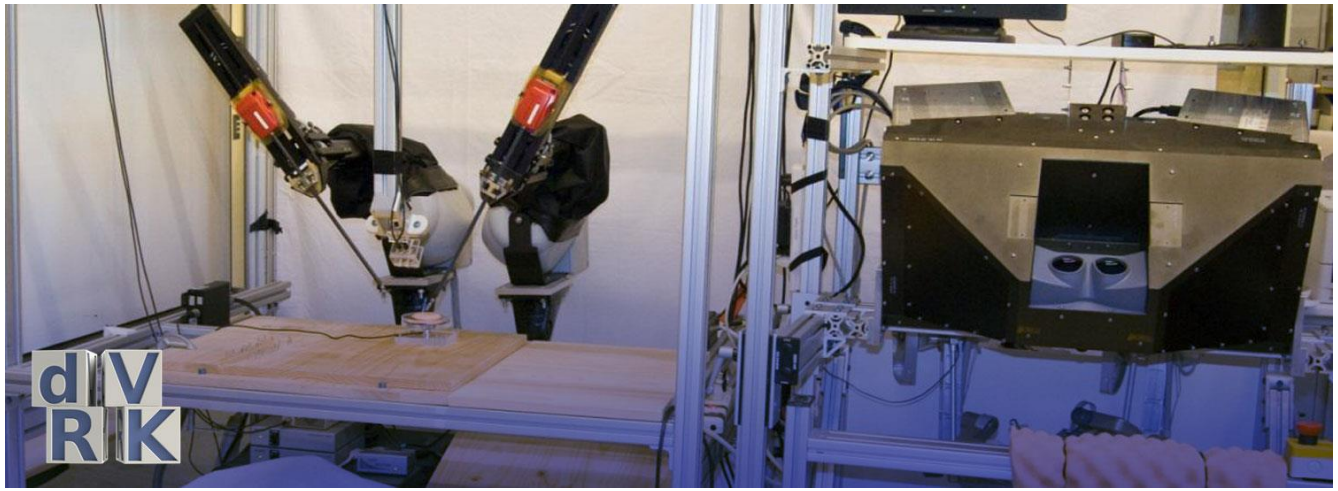


Kazanzides, Peter, et al. "An open-source research kit for the da Vinci® Surgical System." *2014 IEEE international conference on robotics and automation (ICRA)*. IEEE, 2014.
Deguet, Anton, et al. "The cisst libraries for computer assisted intervention systems." *MICCAI Workshop on Systems and Arch. for Computer Assisted Interventions, Midas Journal*. Vol. 71. 2008.

Medical robotics research platforms

jhu-cisst/**cisst-saw**

Meta project to compile cisst libraries along with SAW components



- The daVinci Research Kit (dVRK) is a community effort for researching telerobotic surgery
- The *cisst* package is a collection of libraries for computer-assisted intervention systems
- The Surgical Assistant Workstation (SAW) is a platform for robotics, stereo vision, and intraoperative imaging

Kazanzides, Peter, et al. "An open-source research kit for the da Vinci® Surgical System." *2014 IEEE international conference on robotics and automation (ICRA)*. IEEE, 2014.
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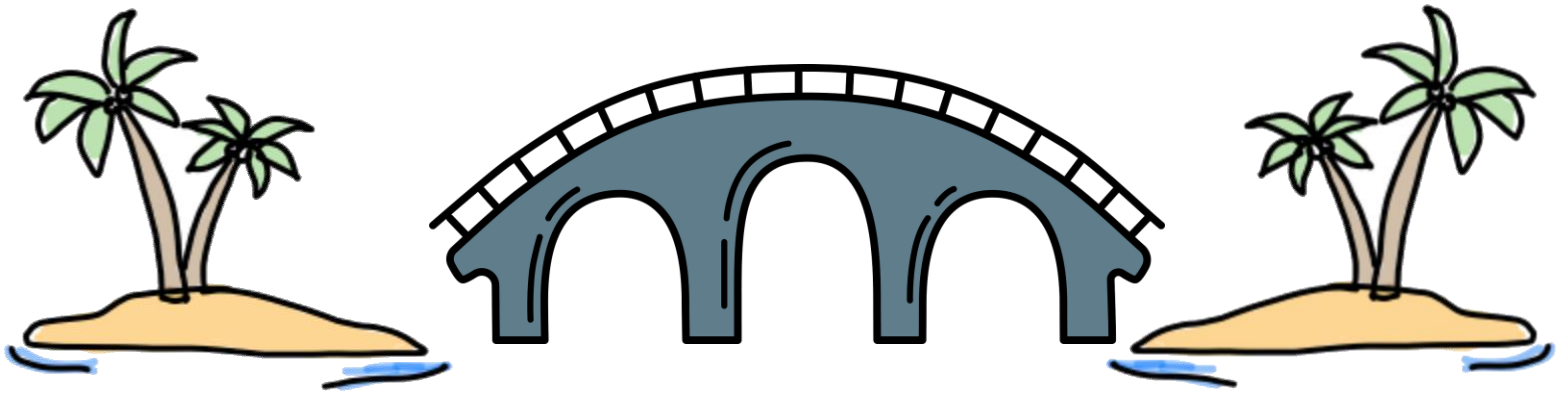
Bridging robotics and IGT platforms

Robotics

Image-guidance



ROS

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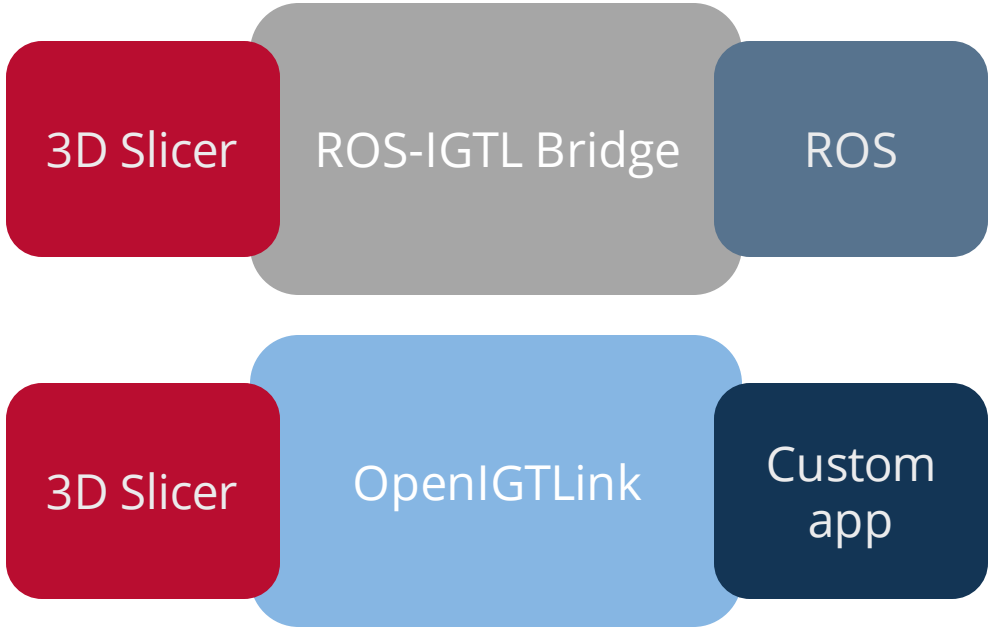
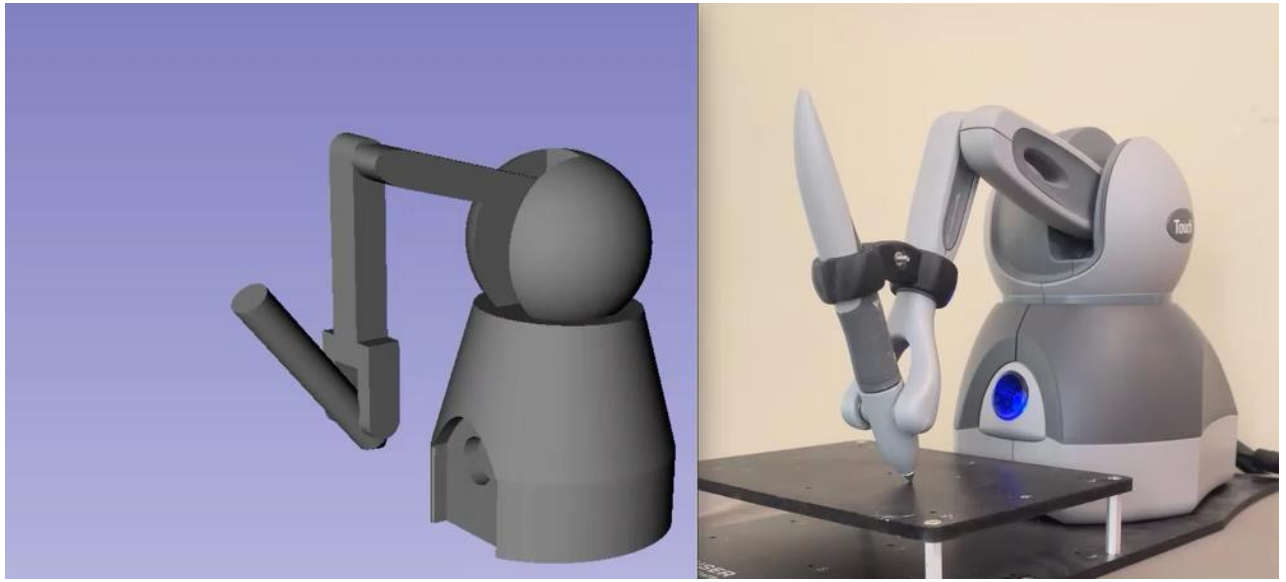
Bridging 3D Slicer and ROS

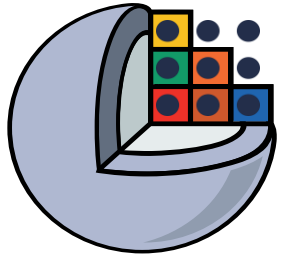




Bridging robotics and IGT platforms

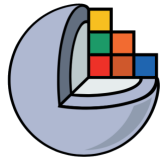
Robotics

ROS



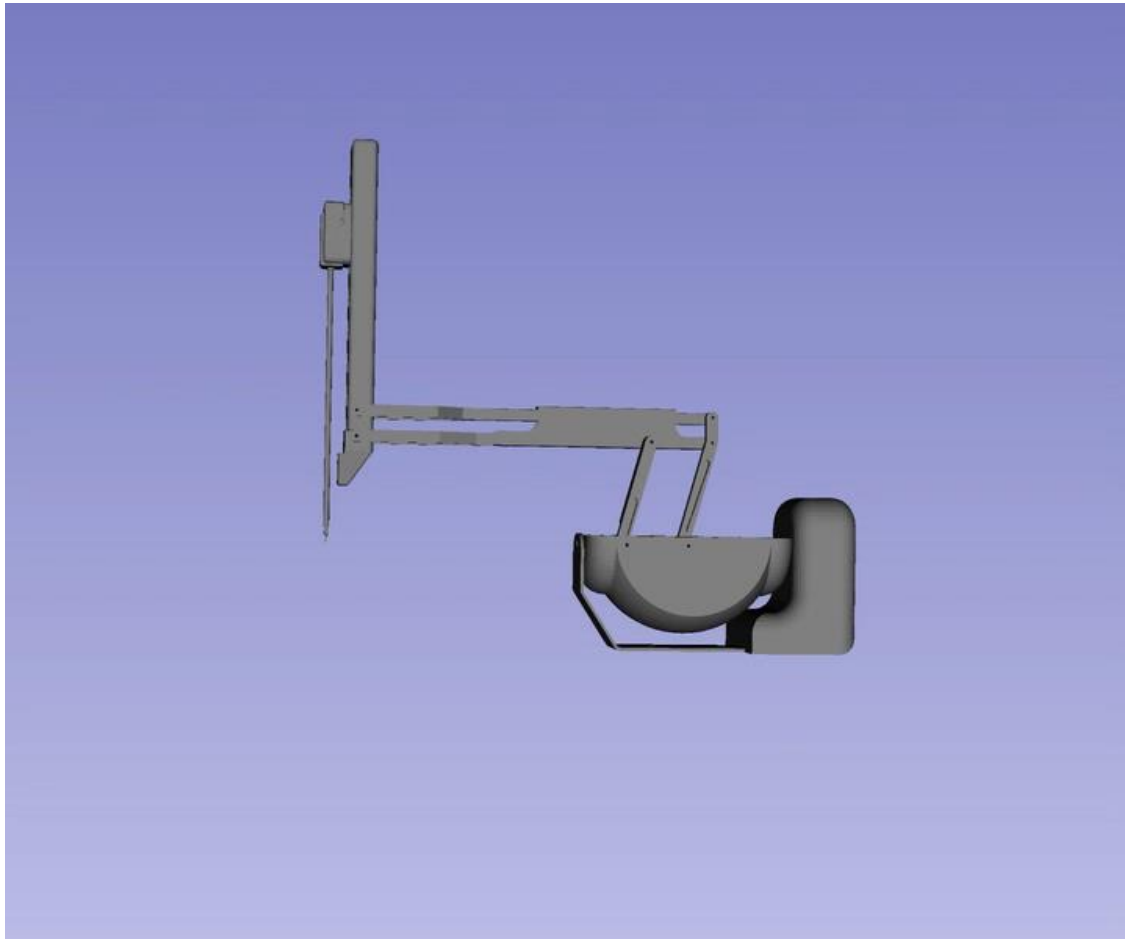
ROS2

Image-guidance



SlicerROS2

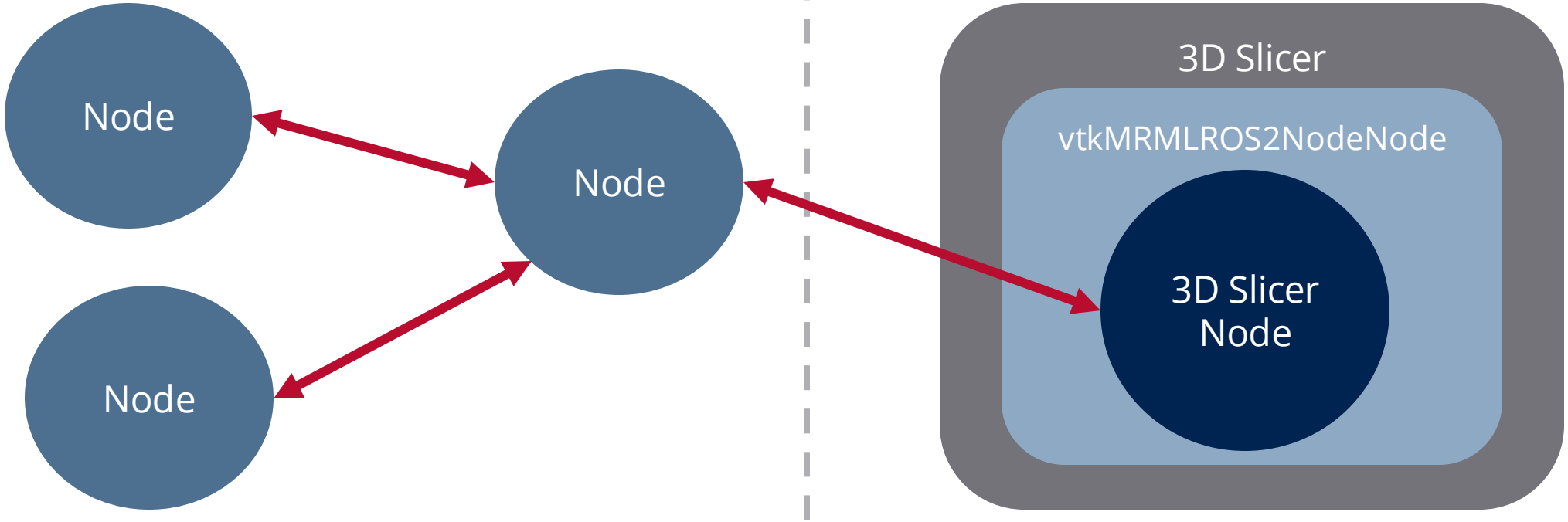
- We built SlicerROS2 to give developers access to the full suite of tools in 3D Slicer & ROS at the same time
- The platform can be used to prototype image-guided robotic systems



How does it work?

3D Slicer is treated like a ROS node

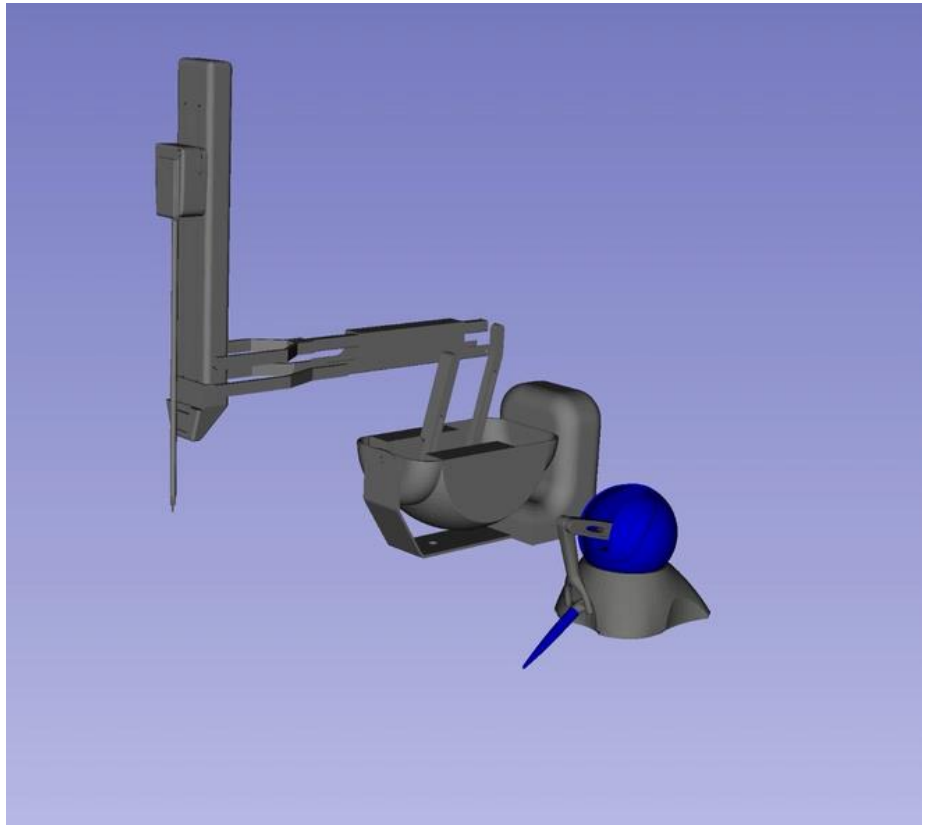
ROS communication mechanisms are packaged as MRML nodes

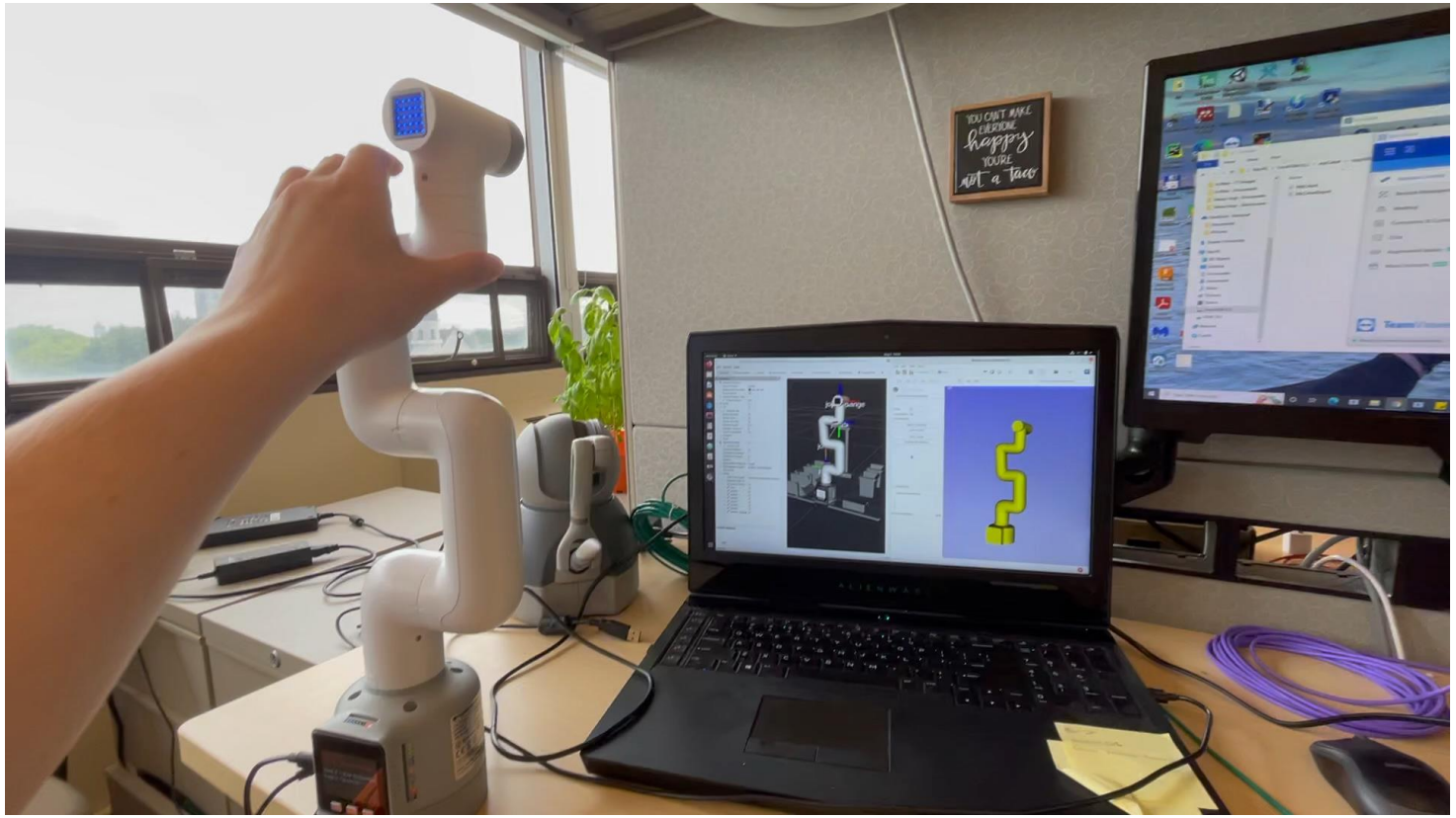


ROS side

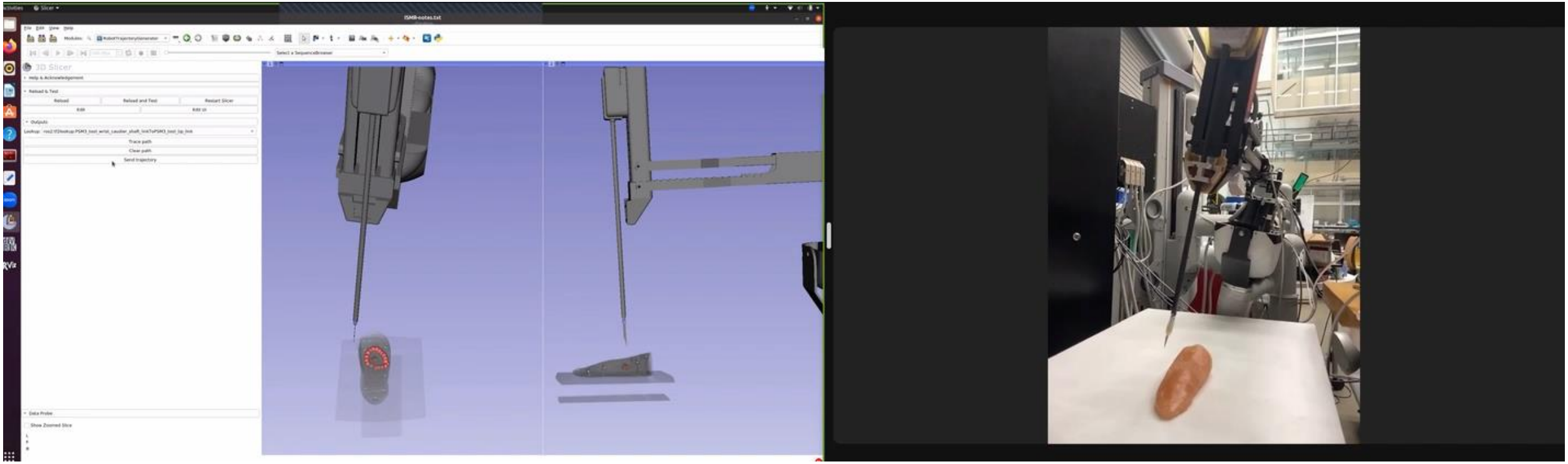
3D Slicer side

SlicerROS2 in action





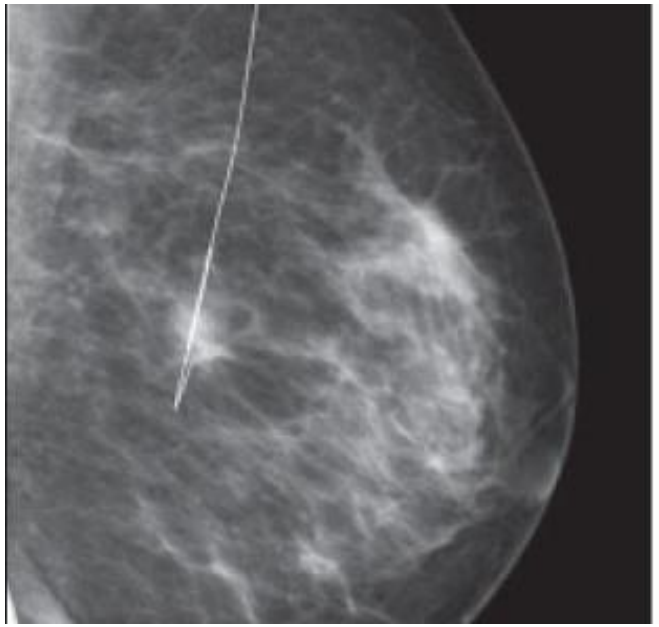
SlicerROS2 in action

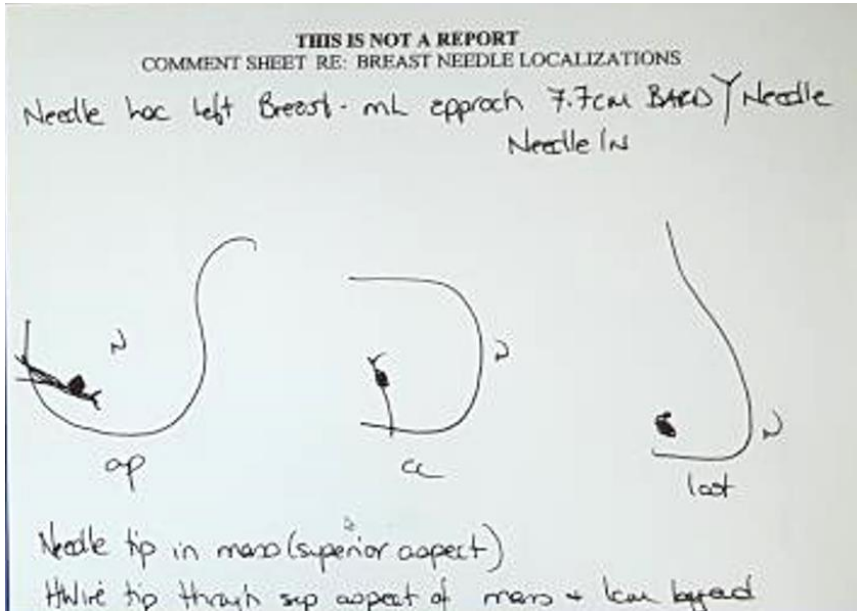


- Part of a collaboration with Dr. Axel Krieger & the IMERSE Lab at JHU (https://imerse.lcsr.jhu.edu)
- Tongue tumor resection with the DaVinci robot

Clinical example:
Breast conserving surgery

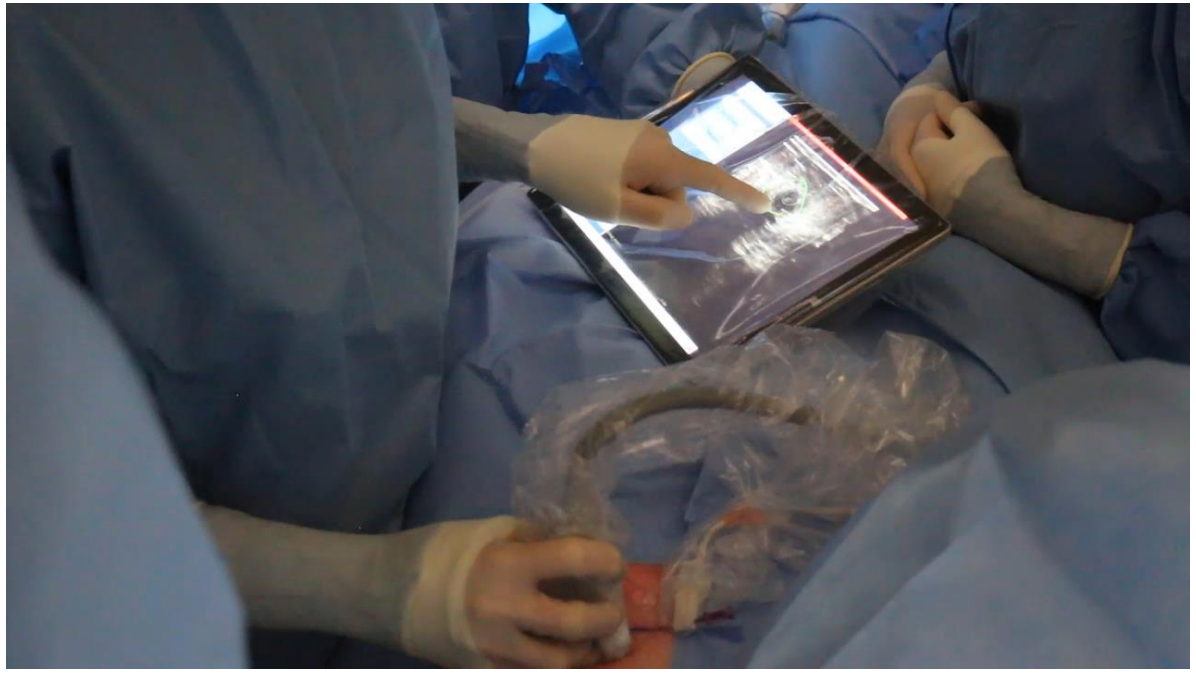
- Breast conserving surgery (BCS) is a common treatment option for breast cancer patients
- Over 30% of these procedures result in incomplete tumor resection

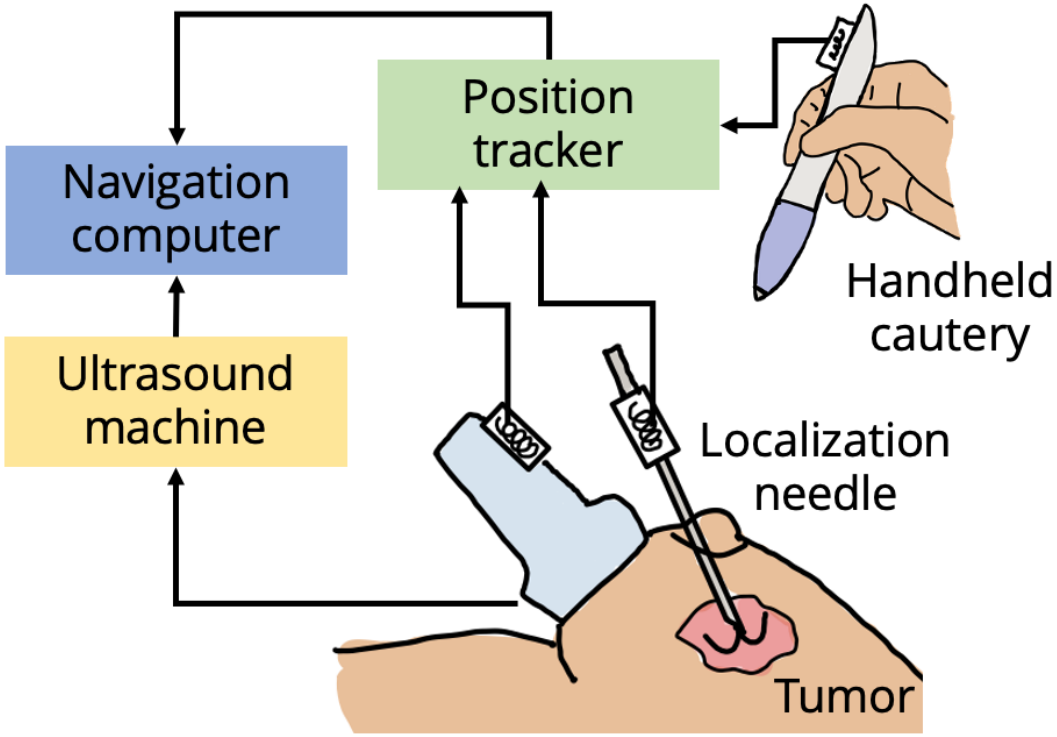




NaviKnife

- The *NaviKnife* system is a platform developed at Queen's University that uses electromagnetic (EM) navigation to localize the tumor in BCS
- Built entirely with SlicerIGT

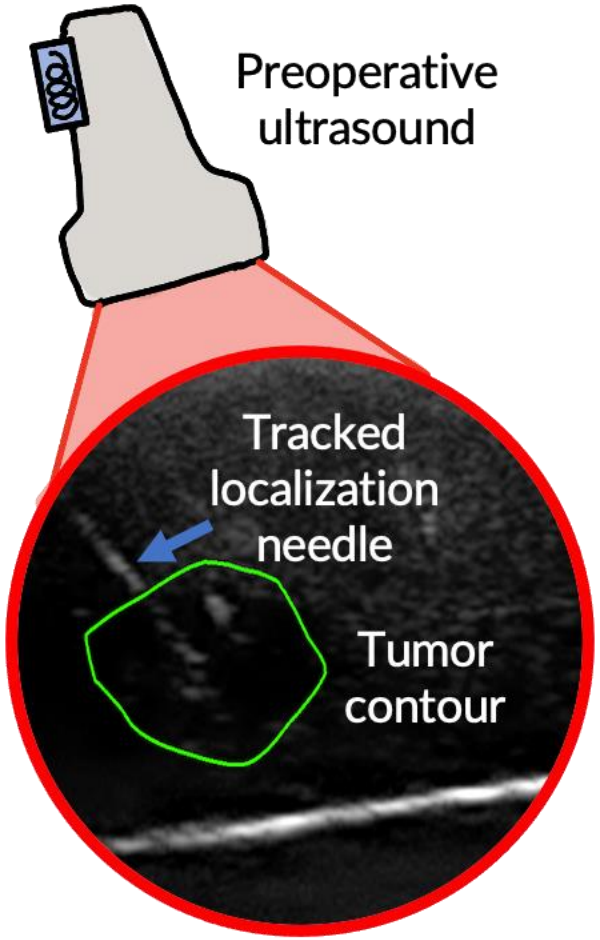


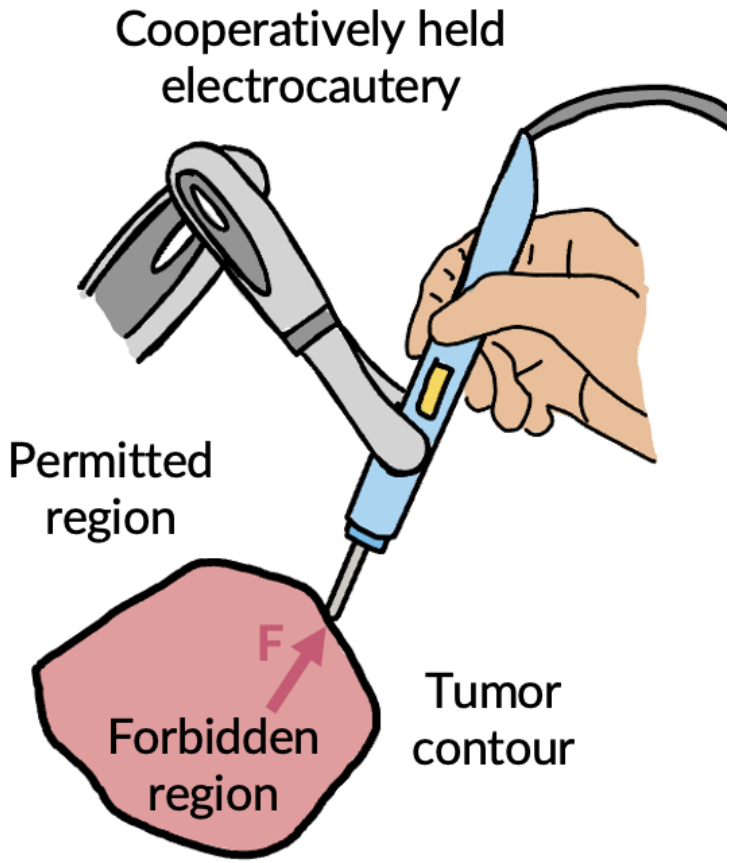


Ungi, Tamas, et al. "Navigated breast tumor excision using electromagnetically tracked ultrasound and surgical instruments." *IEEE Transactions on Biomedical Engineering* 63.3 (2015): 600-606.

Forbidden region virtual fixture

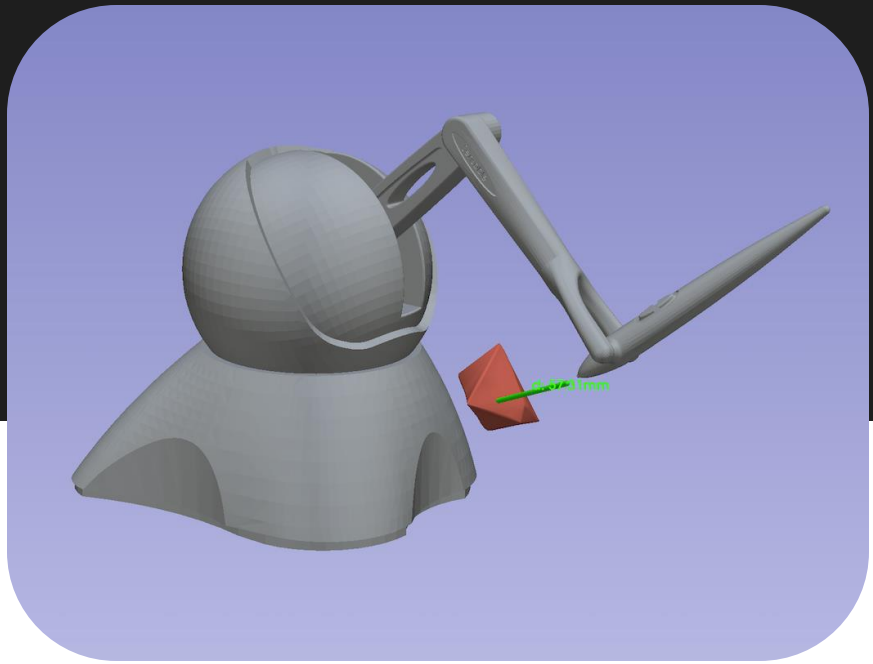
- Tracked ultrasound and tumor contour identification done in NaviKnife interface
- Haptic feedback actuated with the Omni Bundle robot



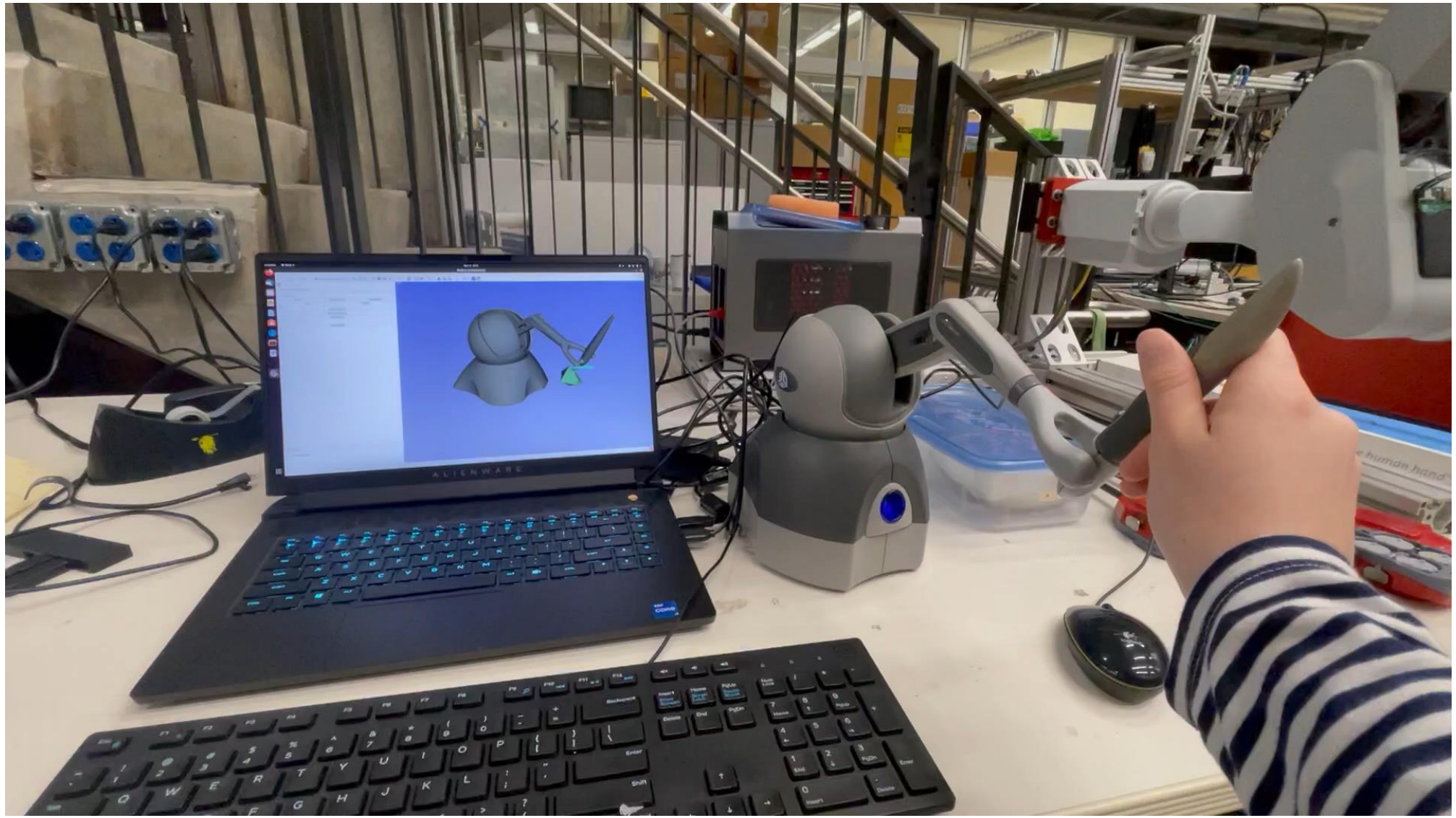


Virtual fixture implementation

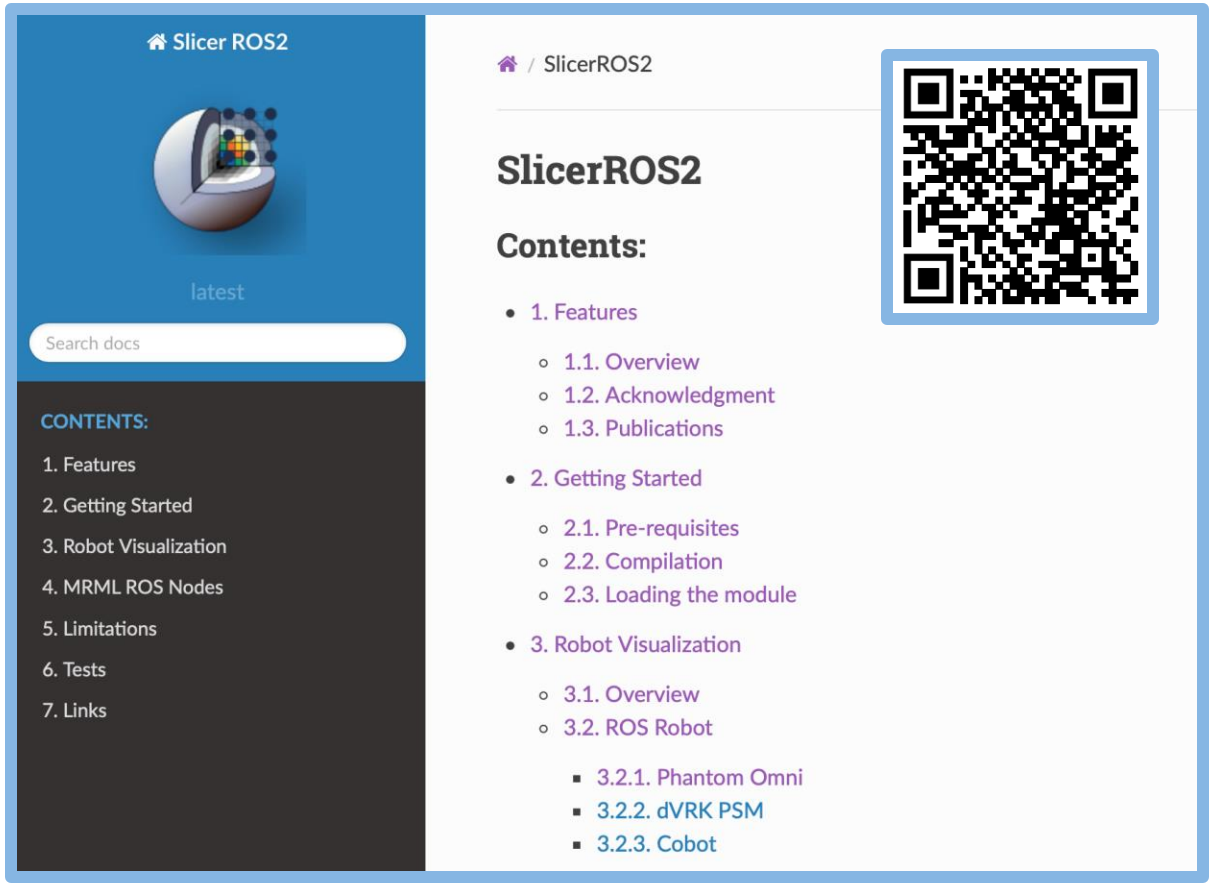
```
position_subscriber = self.ros2Node.CreateAndAddSubscriberNode("vtkMRMLROS2SubscriberPoseStampedNode", "/arm/measured_cp")
feedback_publisher = self.ros2Node.CreateAndAddPublisherNode("vtkMRMLROS2PublisherPoseStampedNode", "/arm/servo_cp")
release_publisher = self.ros2Node.CreateAndAddPublisherNode("vtkMRMLROS2PublisherWrenchStampedNode", "/arm/servo_cf")

breachWarningNode = slicer.mrmlScene.GetFirstNodeByName("BreachWarning")
self.addObserver(self.logic.breachWarningNode, vtk.vtkCommand.ModifiedEvent, self.logic.virtualFixture)

def virtualFixture(self):

    if (breachWarningNode.isToolTipInsideModel()):
        pose = vtk.vtkMatrix4x4()
        position_subscriber.GetLastMessage(pose)
        feedback_publisher.Publish(pose)

    else:
        wrench = vtk.vtkDoubleArray()
        release_publisher.Publish(wrench)
```



- Built on top of the NaviKnife architecture
- Only 13 lines of python code!


ALIENWARE

Conclusions



https://slicer-ros2.readthedocs.io/en/latest/

- Get started with SlicerROS2 today!
- Reach out if you have any questions, requests for additional features, feedback, etc.

Contact info: laura.connolly@queensu.ca

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Developers and collaborators:

SlicerROS2: Anton Deguet, Aravind S. Kumar, Simon Leonard, Junichi Tokuda, Axel Krieger, Peter Kazanzides, Russell H. Taylor

SlicerIGT: Andras Lasso, Tamas Ungi, Csaba Pinter, Kyle Sunderland