3D Slicer Tutorial: Prototyping Surgical Robot System Using ROS and 3D Slicer

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Background

- Growing Interest in Robot Assisted Interventions
  - Robot-assisted laparoscopy
  - Robotic catheter systems
  - Robotic radiosurgery, etc.
- R&D of Surgical Robot System
  - Image processing and visualization for surgical planning
  - Kinematics and motion planning for robot control
  - Device management and control

➔ Requires a wide range of tools and methods developed in robotics and medical image computing fields

Background (2)

- Common research platforms
  - Medical Image Computing
    - 3D Slicer
    - MITK
    - NifTK
    - OsiriX…

    } Data sharing interface based on OpenIGTLink
  - Medical Robotics
    - da Vinci Toolkit (dVRK)
    - Raven II
    - KUKA Lightweight Robot

    } Integrated with Robot Operating System (ROS)

➔ Need for a bridge between ROS and OpenIGTLink

Objective of This Tutorial

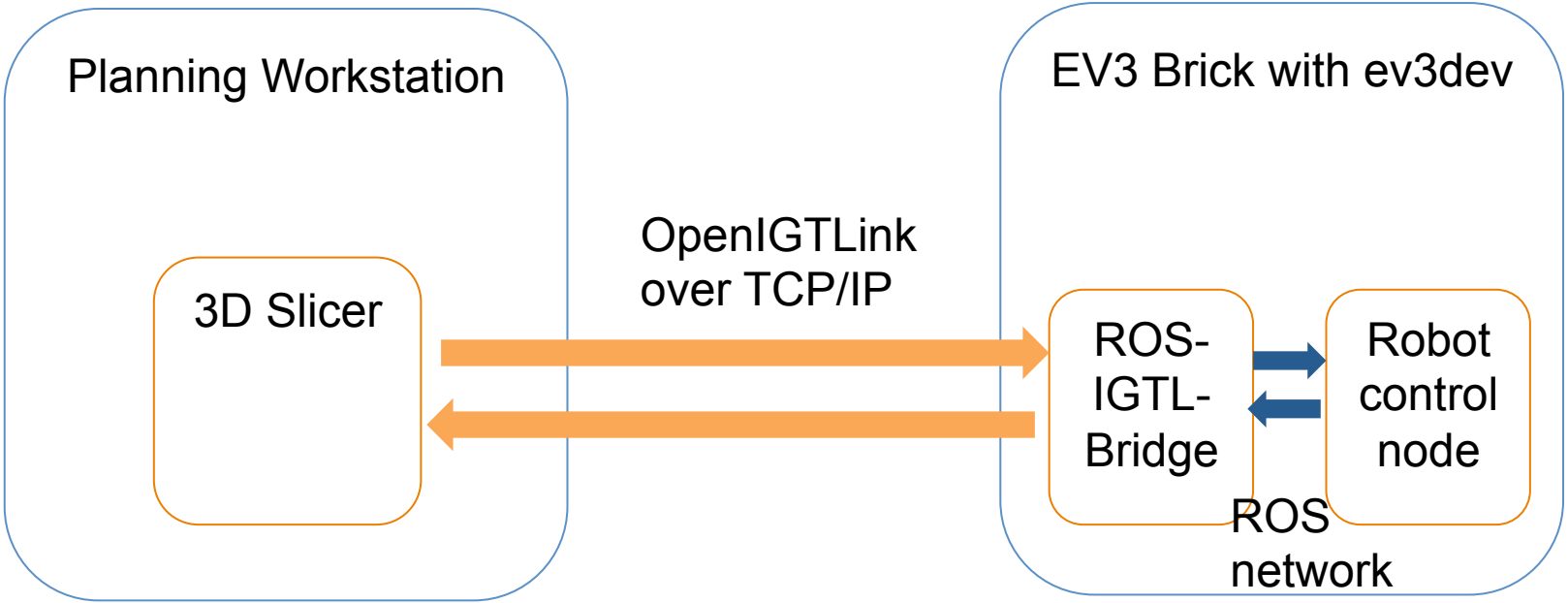
- Prototype surgical robot system using widely-available software and hardware
  - 3D Slicer as planning interface
  - Lego Mindstorms as robot hardware
  - Robot Operating System (ROS) as robot control software

- Through this tutorial, you can:
  - Learn software architecture of surgical robot systems
  - Acquire hands-on experience of software-hardware integration for medical robotics

Prerequisite

- 3D Slicer Version 4.6 or later
- Lego Mindstorms EV3 with WiFi dongle
- ev3dev – Debian Linux for Mindstorms EV3
  - http://www.ev3dev.org
- ROS-IGTL-Bridge
  - https://github.com/openigtlink/ROS-IGTL-Bridge

Architecture

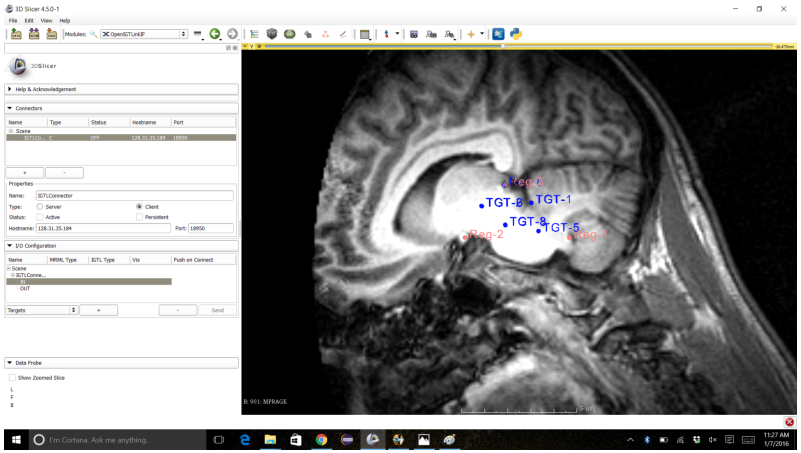


Tasks in Each Compenent

- 3D Slicer
  - Medical Image Display
  - Segmentation
  - Procedure Planning
  - Pre/Intra Image Registration
  - Tracker support
- OpenIGTLink
  - Communication Protocol
  - Transformation manager
- ROS
  - Robot Control
  - Path Planning
  - Image Libraries
  - Sensor Integration
  - Simulation
- ROS-IGTL-Bridge
  - Convert ROS topics to OpenIGTLink
  - Transformation manager
- Controller Node
  - Control actuators

Step 1: Preoperative Planning

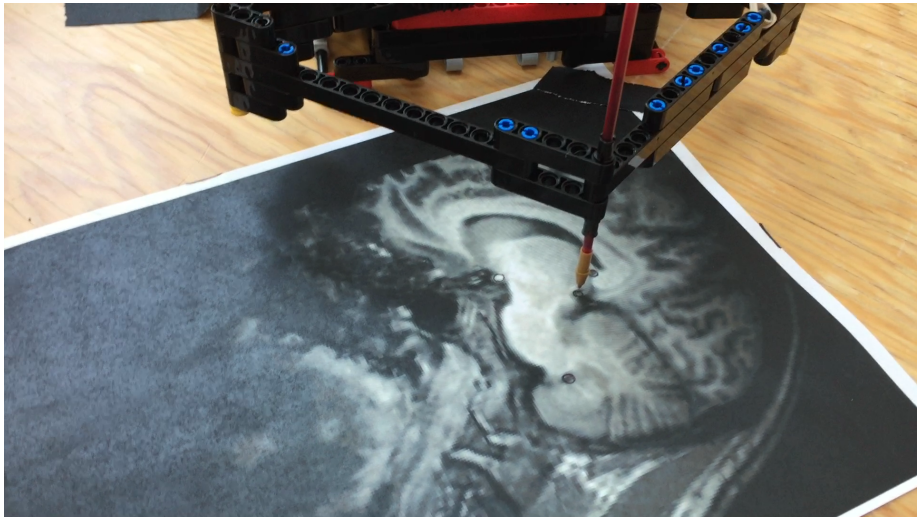
- Pre-operative MRI Brain Scan
- Mark three distinct points on brain for registration in Slicer
- Plan cut in Brain Stem for tumor removal in Slicer



Step 2: Pre/Intraoperative Registration

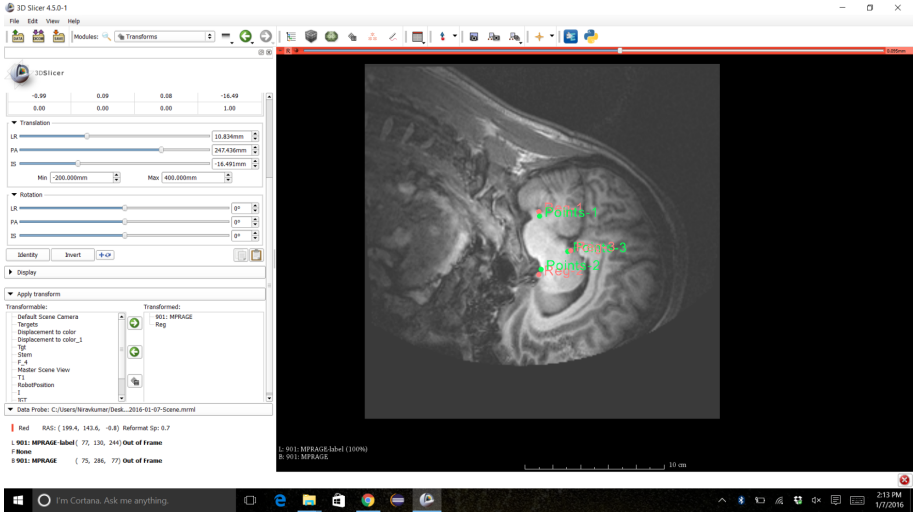
- Place scalpel over three distinct points for registration

- Send registration points through ROS to Slicer



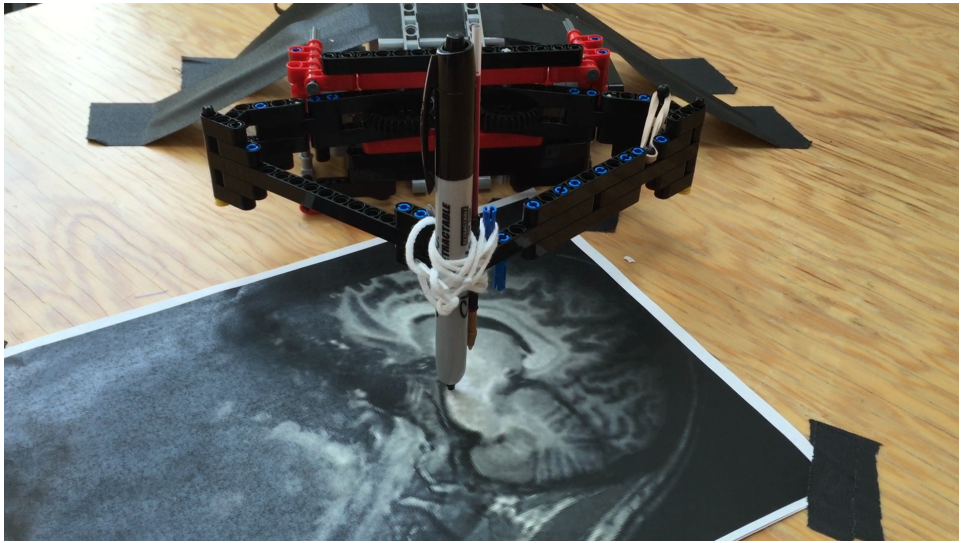
Step 2: Pre/Intraoperative Registration (2)

- Perform registration in Slicer
- Send target points for cut to ROS



Step 3: Robotic Procedure

- Robot path is planned and sent to robot
- Robotic traces the planned trajectory



Conclusion

- Integration of 3D Slicer and ROS
  - Provide access to resources developed in two communities
  - Allows quick prototyping of surgical robot systems
  - Thanks to a wide variety of hardware supported by ROS, the system can be scaled up easily without changing the system architecture