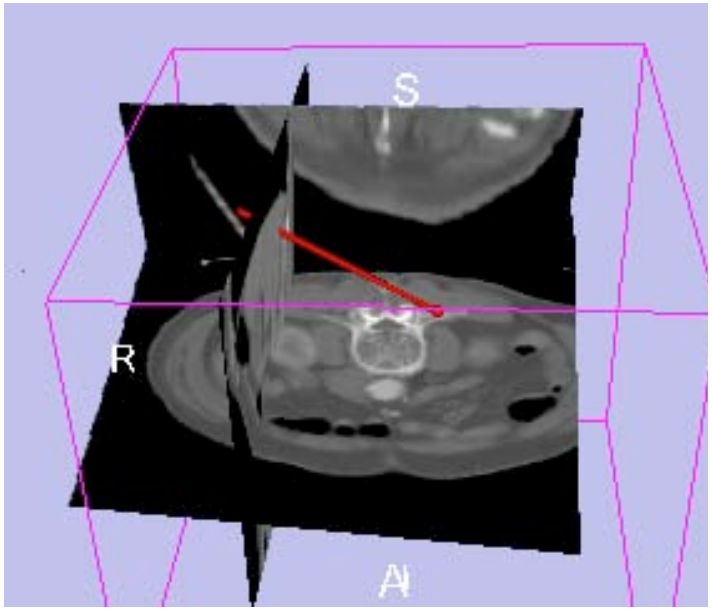
Image Guided Therapy in Slicer3

Introduction to Navigation using OpenIGTLink

Danielle Pace, B.CmpH



Acknowledgements

Surgical Planning Lab, Harvard Medical School

Junichi Tokuda, Haiying Liu, Nobuhiko Hata, Steve Pieper, Ron Kikinis

National Alliance for Medical Image Computing

National Center for Image-Guided Therapy

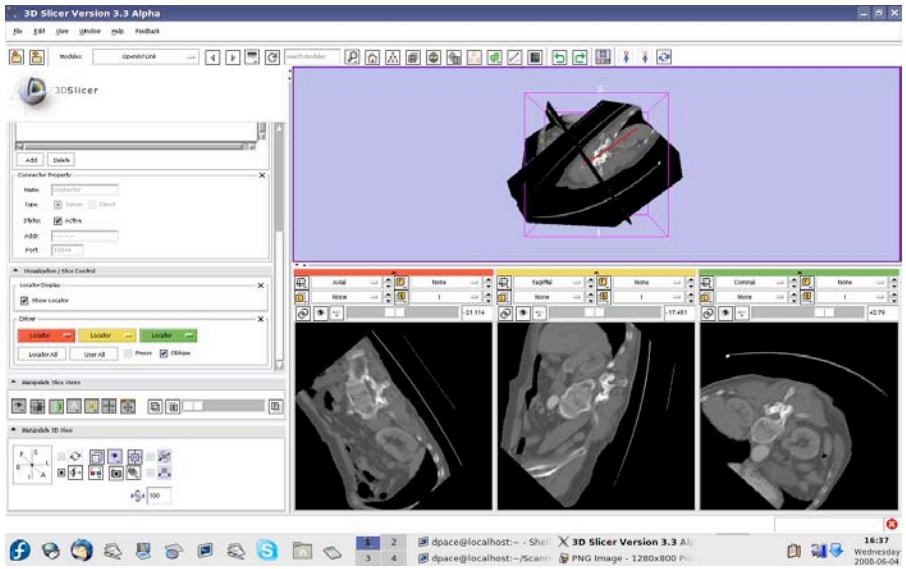
Robarts Research Institute

Chris Wedlake

Learning objective

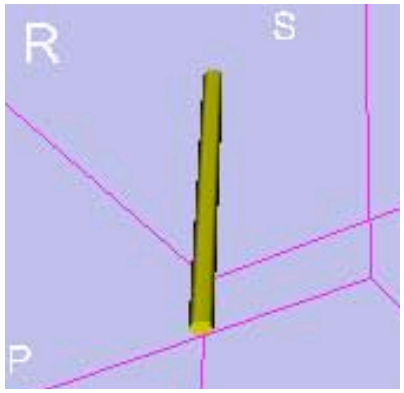
Following this tutorial, you will:

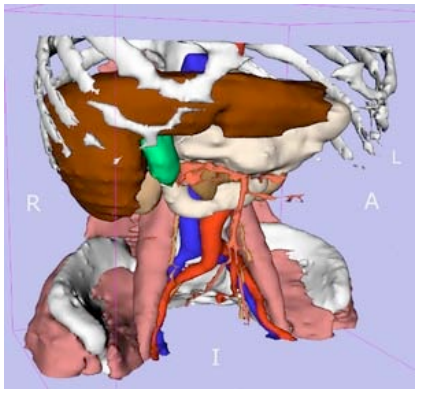
- Understand how to use tracking devices with Slicer3 using the OpenIGTLink module
- OpenIGTLink can also be used to interface with other devices, such as imaging devices and medical robots



Material

- This course requires a simple VTK tool model plus *either* the SPL-PNL brain atlas or the SPL abdominal atlas:





VTK model:
http://wiki.na-mic.org/Wiki/index.php/IGT:ToolKit/Navigation-tutorial

Brain and abdominal atlases:
http://wiki.na-mic.org/Wiki/index.php/IGT:ToolKit/Datasets

Required software

This tutorial requires the OpenIGTLink Slicer3 module and a tracker simulator:

- For both of these, you have the choice of either downloading a precompiled version (binary) **OR** building it yourself from the source code

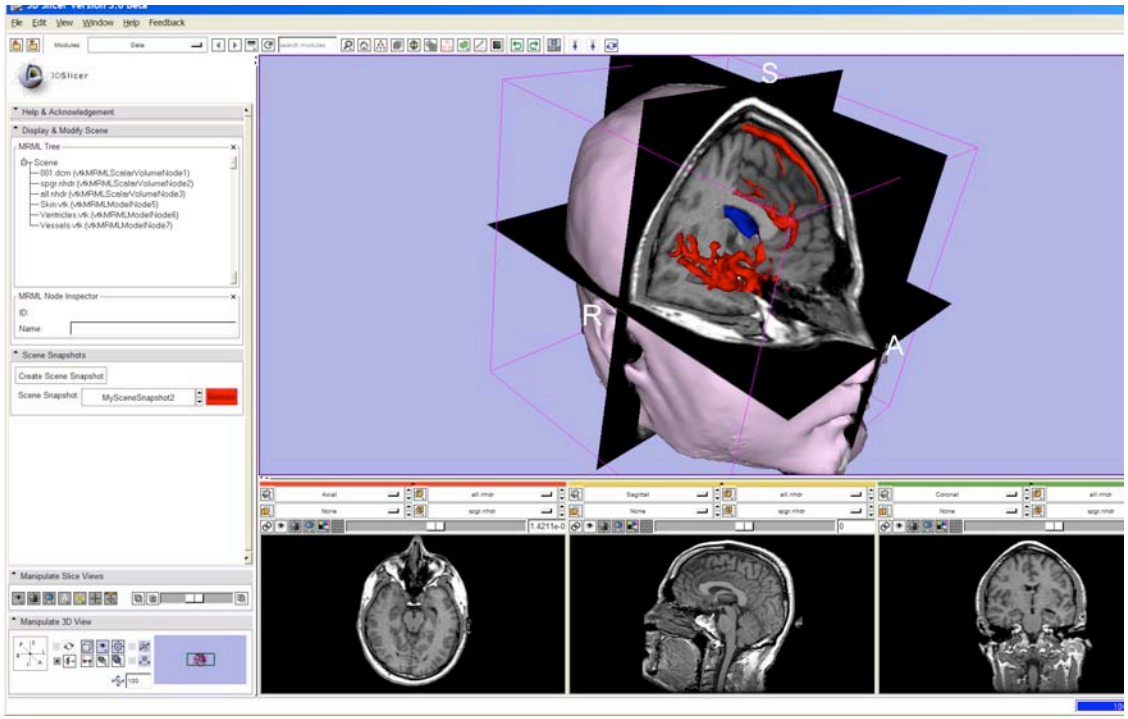
For installation instructions, see the wiki page at http://wiki.na-mic.org/Wiki/index.php/IGT:ToolKit/Navigation-tutorial

Disclaimer: It is the responsibility of the user of 3D Slicer to comply with both the terms of the license and with the applicable laws, regulations and rules.

Prerequisites

- Data Loading and Visualization in Slicer3:

http://wiki.na-mic.org/Wiki/index.php/Slicer:Workshops:Slicer3_Training

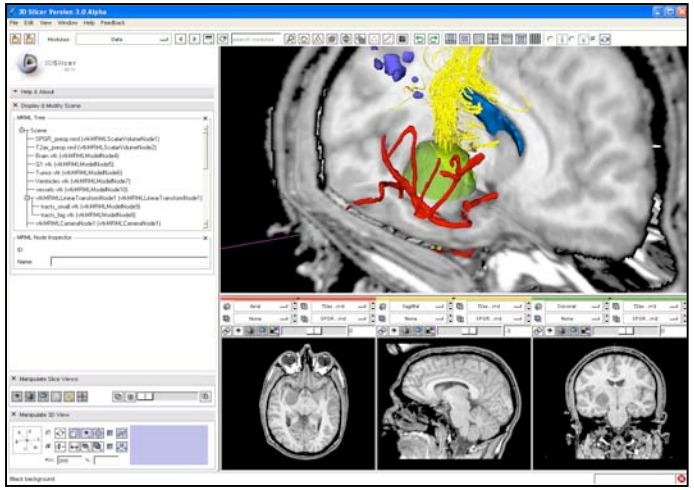


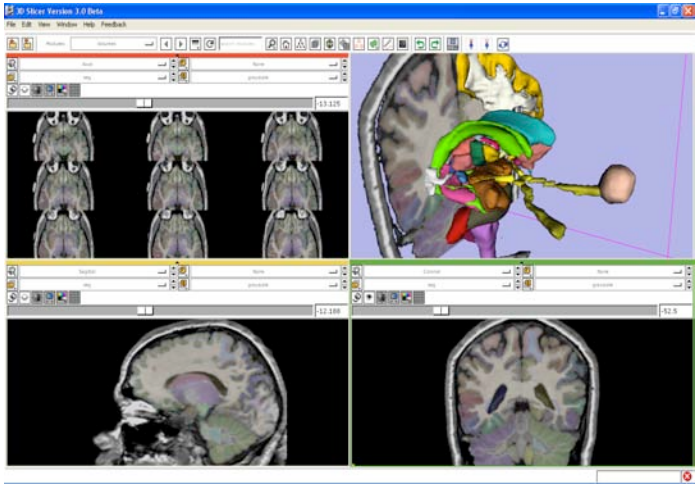
Tutorial outline

1. **Introduction to surgical navigation**
2. Interfacing Slicer3 with external devices using OpenIGTLink
3. Hands-on navigation using a tracking simulator
4. Examples of OpenIGTLink in use

3D Slicer

- Integrates algorithms and utilities for medical image computing research and Image Guided Therapy into a single framework
- Is both an end-user application and a platform for research
- The precompiled program and the source code are both freely downloadable





Courtesy R. Kikinis

Image Guided Therapy (IGT) in Slicer3

Slicer3 has extensive support for IGT, including:

- Visualization
- Registration
- Segmentation
- Model making
- Diffusion Tensor Imaging
- Quantification
- Filtering
- Interfacing to imaging devices, trackers and medical robots

} **Focus of this tutorial**

Navigation in IGT

- Determining the positions and orientations of surgical tools using a tracking system
- Displaying virtual representations of those tools on the screen for the surgeon

Navigation in IGT

- **Selected clinical uses:**
  - Real-time update of tool position and orientation in augmented reality environments (ex. for minimally-invasive cardiac surgery)
  - Image-to-patient registration using tracked pointer tools (ex. for total hip replacement surgery)
  - Image-to-patient registration using tracked intraoperative imaging devices (ex. ultrasound)

In order to perform navigation, software must be able to receive position and orientation data from tracking devices!

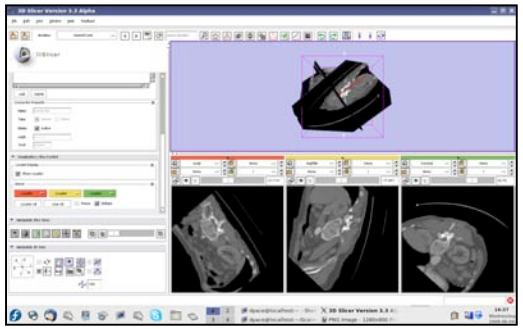
Tutorial outline

1. Introduction to surgical navigation
2. **Interfacing Slicer3 with external devices using OpenIGTLink**
3. Hands-on navigation using a tracking simulator
4. Examples of OpenIGTLink in use

What is OpenIGTLink?

- OpenIGTLink is a communication protocol that allows Slicer3 to communicate with external devices

What is OpenIGTLink?



Slicer3 OpenIGTLink module

OpenIGTLink ⟷

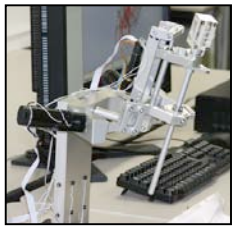
Imaging devices (ex MRI, US)

OpenIGTLink ⟷

Tracking devices

OpenIGTLink ⟷

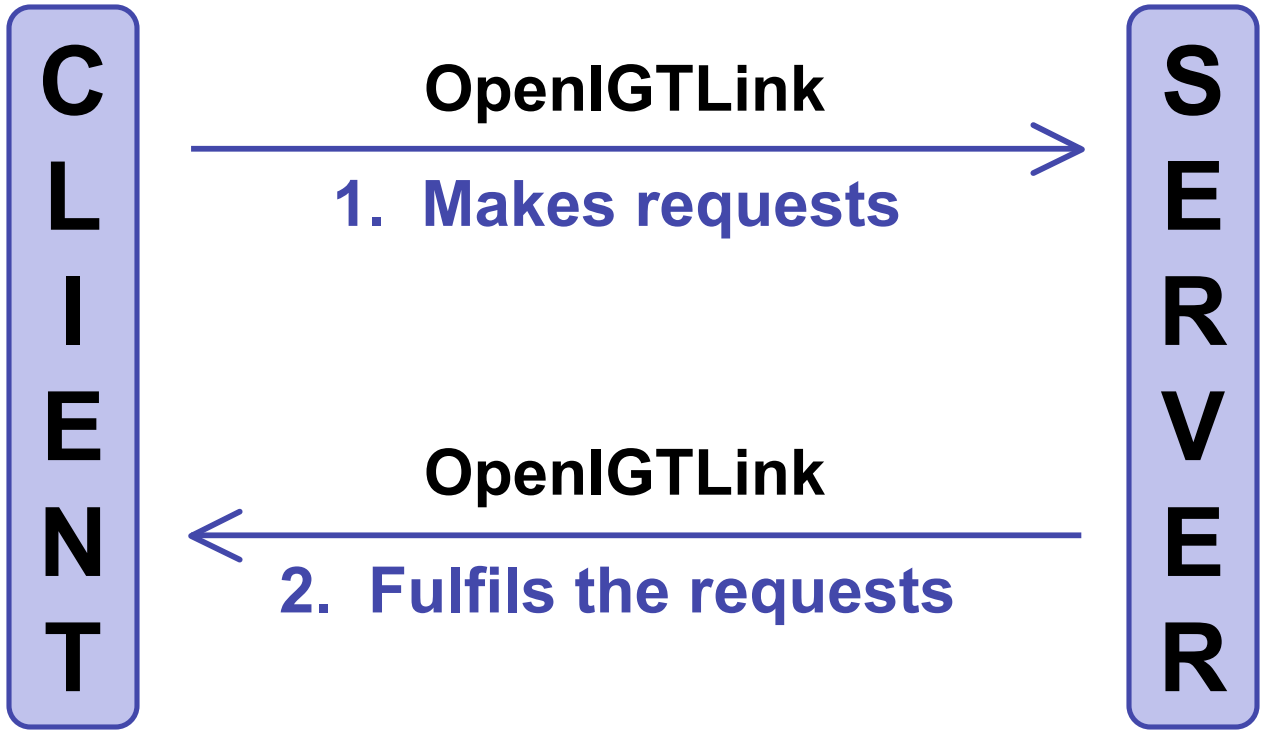
Medical robots



Courtesy www.ncigt.org, www.ndigital.com, www.slicer.org

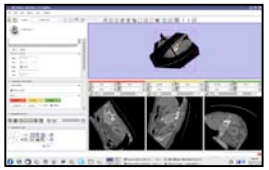
OpenIGTLink

- OpenIGTLink uses a “Client-Server” architecture.



OpenIGTLink

- Surgical robot example:



CLIENT

OpenIGTLink

1. Makes requests

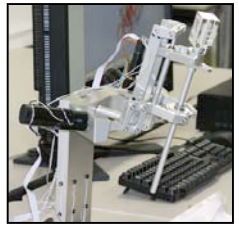
Ex. Get current coordinate

OpenIGTLink

2. Fulfils the requests

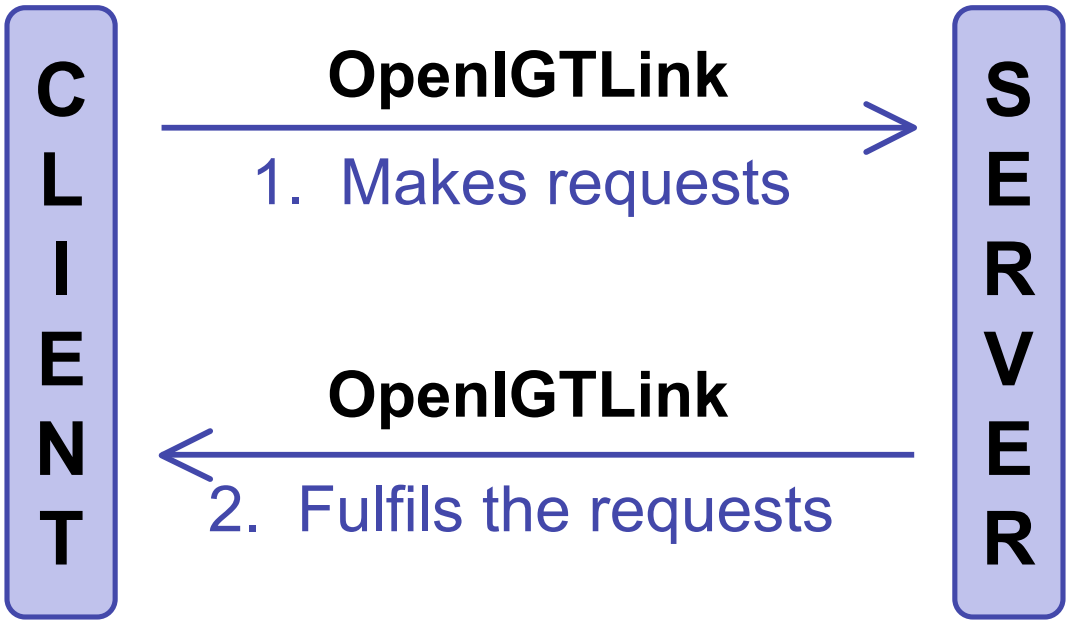
Ex. Returns current coordinate

SERVER



OpenIGTLink

- The OpenIGTLink protocol specifies the structure of the messages sent between the client and the server
- Slicer3 can be either the client or the server, depending on the application



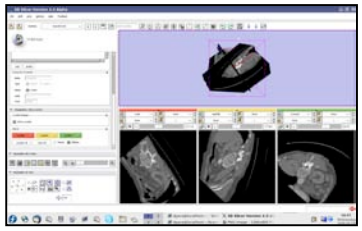
The OpenIGTLink module in Slicer3

- OpenIGTLink is a protocol

- There is an OpenIGTLink module in Slicer3 that implements the protocol so that Slicer3 can communicate with external devices

OpenIGTLink and IGSTK

- IGSTK = Image-Guided Surgery Tool Kit
- OpenIGTLink functionality has been added to IGSTK: you can now use IGSTK to write programs that interact with both Slicer3 and the physical device



Slicer3
(client or server)

OpenIGTLink

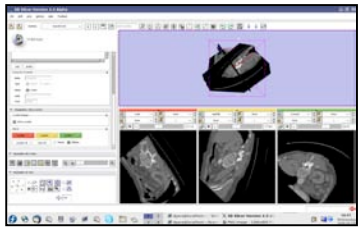
IGSTK program
(client or server)

Device ex. tracker

Courtesy www.ndigital.com

The tracking simulator

- In this tutorial, a tracking simulator is used instead of using an actual tracking device
- The tracking simulator acts as the **client** to send simulated data to Slicer3 (the server) over OpenIGTLink



Slicer3
(server)

OpenIGTLink

TRACKING SIMULATOR
(client)

Tutorial outline

1. Introduction to surgical navigation
2. Interfacing Slicer3 with external devices using OpenIGTLink
3. **Hands-on navigation using a tracking simulator**
4. Examples of OpenIGTLink in use

Hands-on navigation

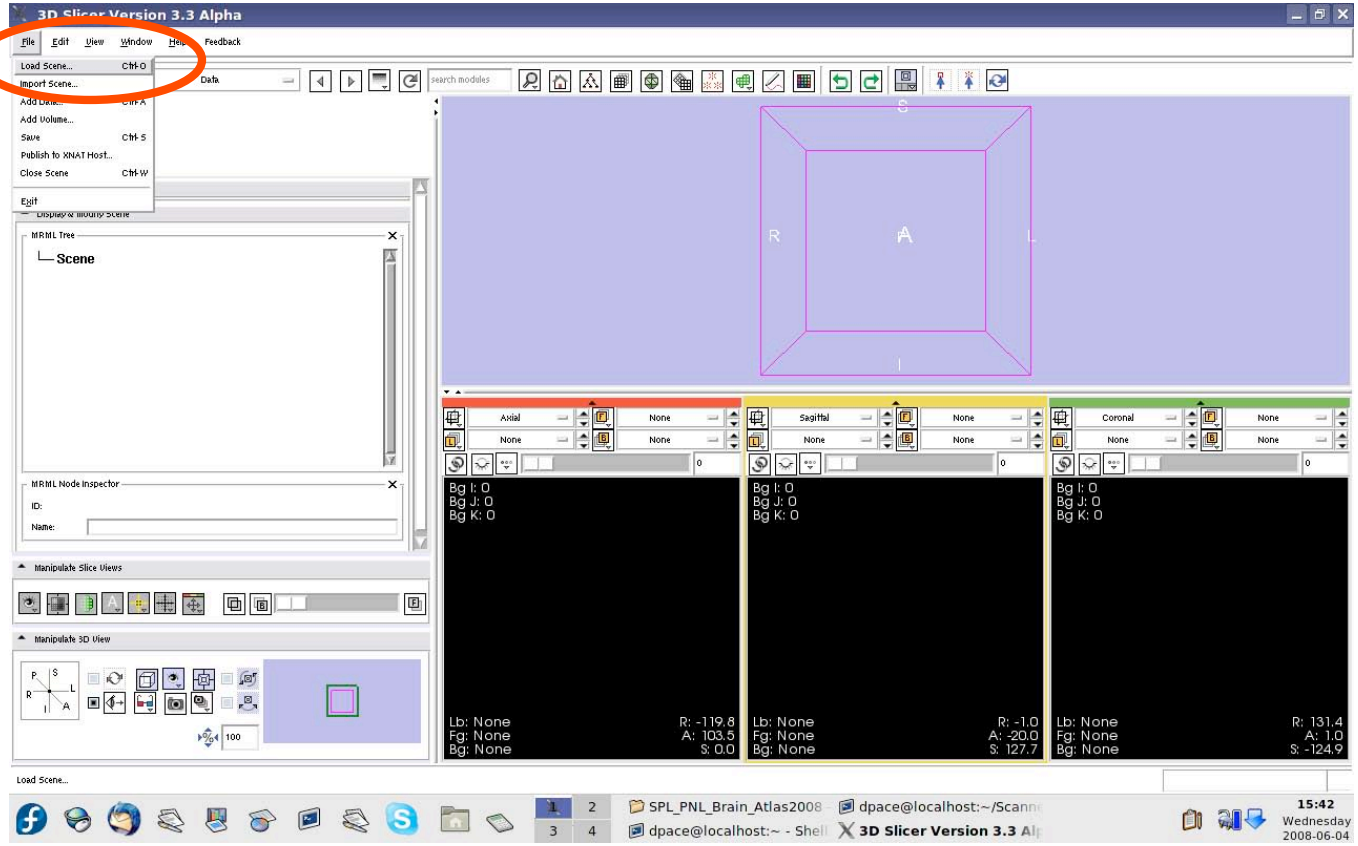
- Using a tracking simulator, you will learn how to:
  - Set up an OpenIGTLink connection in Slicer3
  - Show the resulting transforms using both the Slicer3 “locator” and a vtk model
  - Add a calibration matrix
  - Reslice image volumes using the tracker transform

Note

- Although the screenshots used in this tutorial use the SPL abdominal atlas, the SPL-PNL brain atlas can also be used

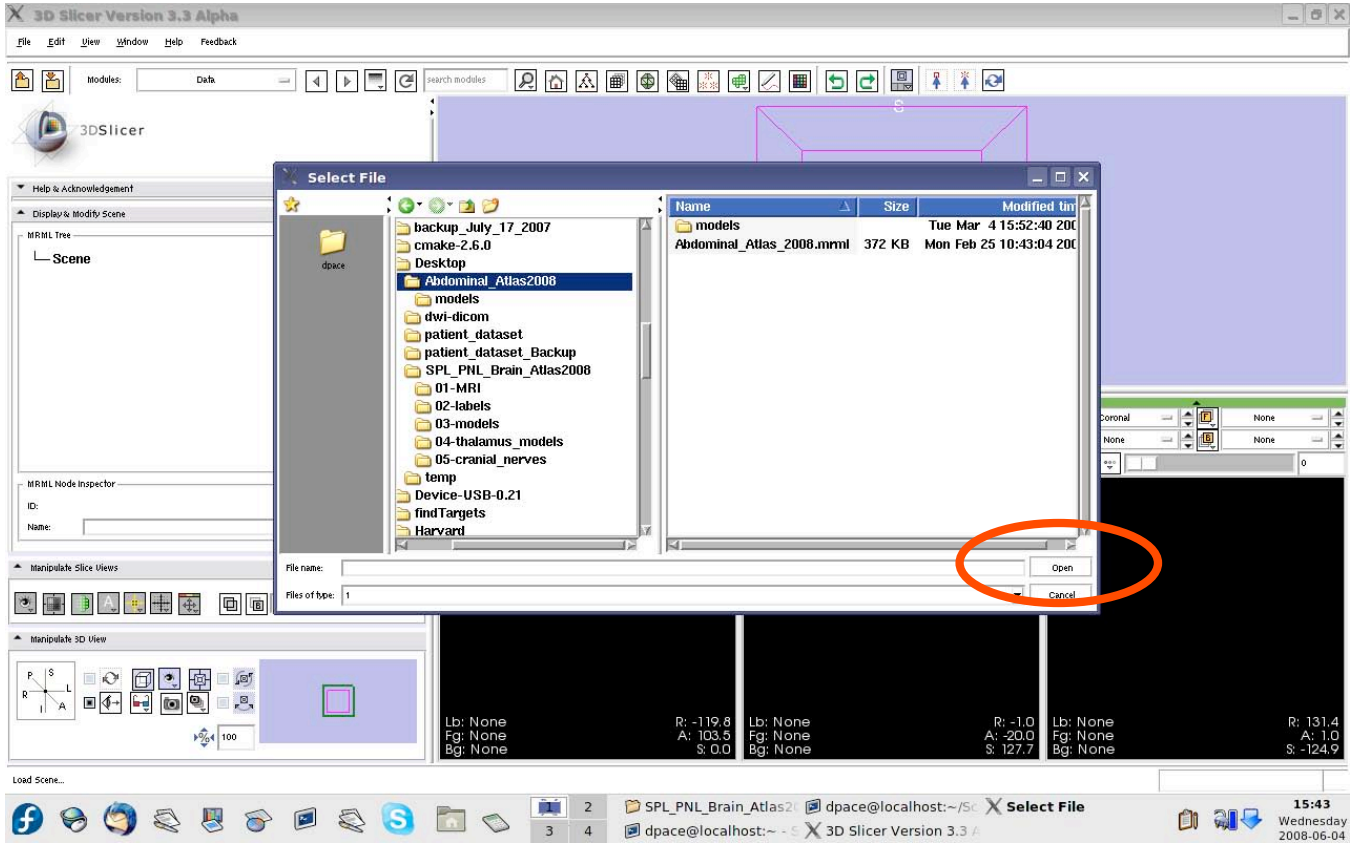
Load the atlas

Click on File -> Load Scene



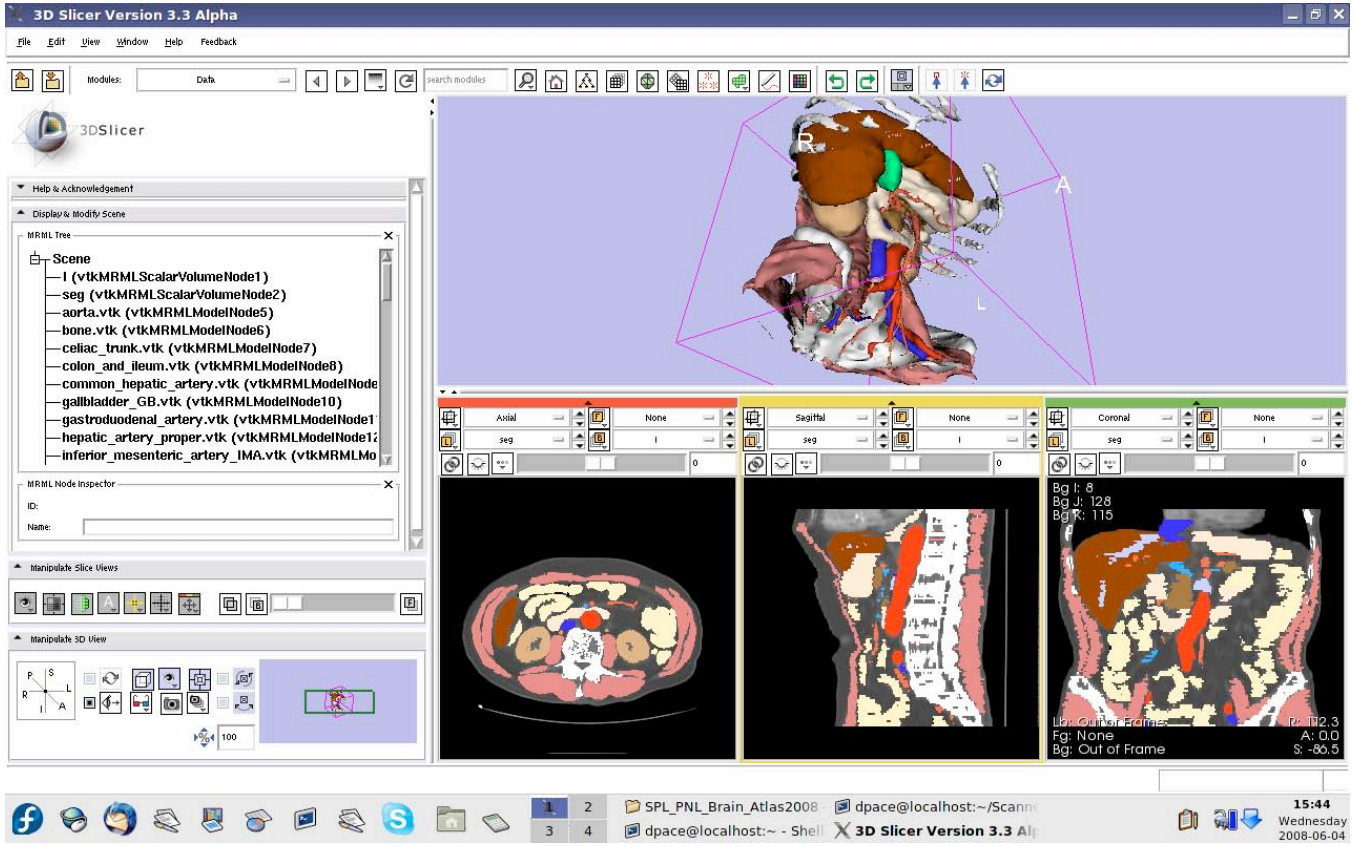
Load the atlas

Select the scene file for the atlas (brain_atlas_2008.mrml or Abdominal_Atlas_2008) and click “Open”



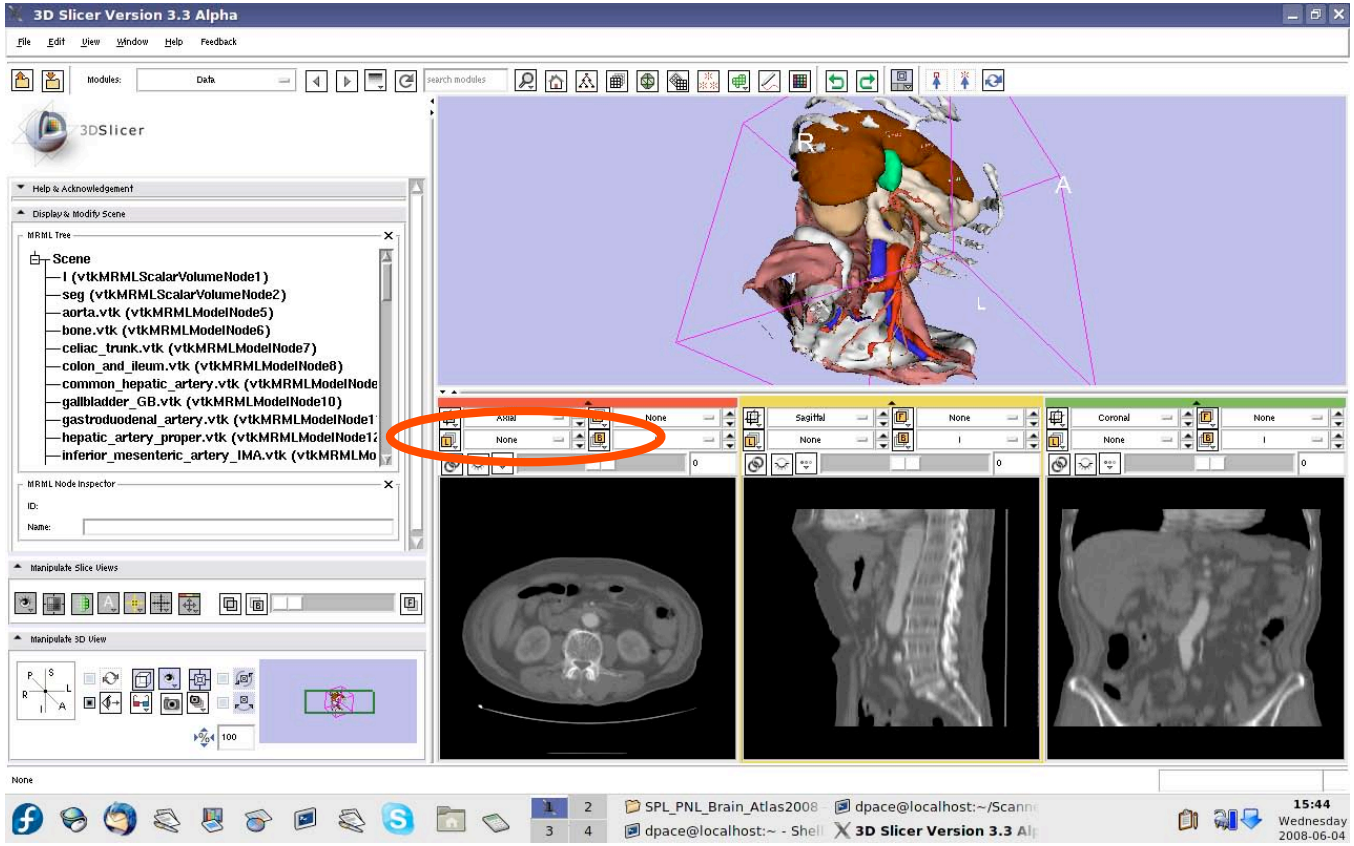
Load the atlas

All of the atlas components are shown in the MRML scene within the Data module



Load the atlas

If you are using the abdominal atlas, change the label map to “None”

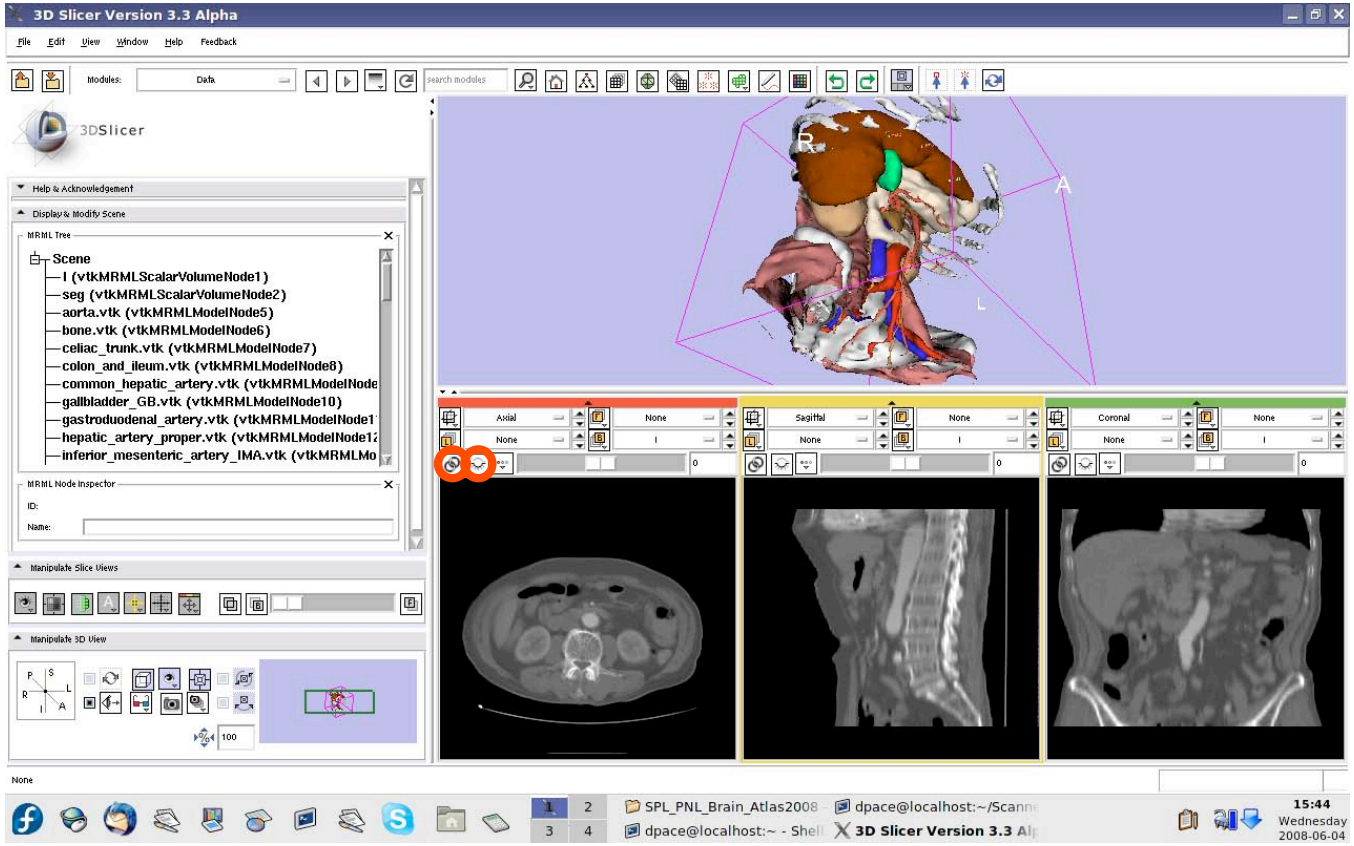


Load the atlas

If you are using the brain atlas, turn off the visibility of the images:

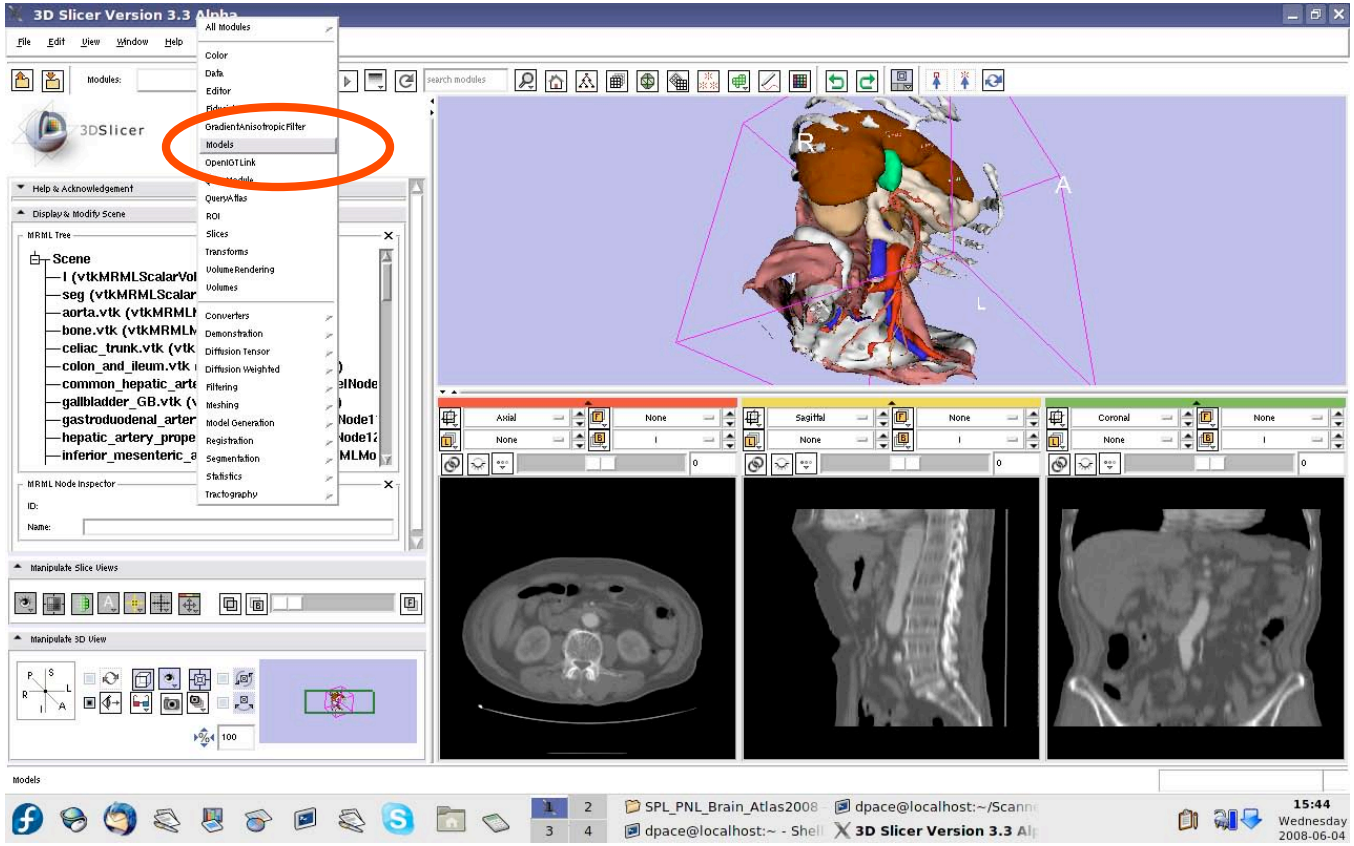
Click the “Link” button

Click the “Visibility” button



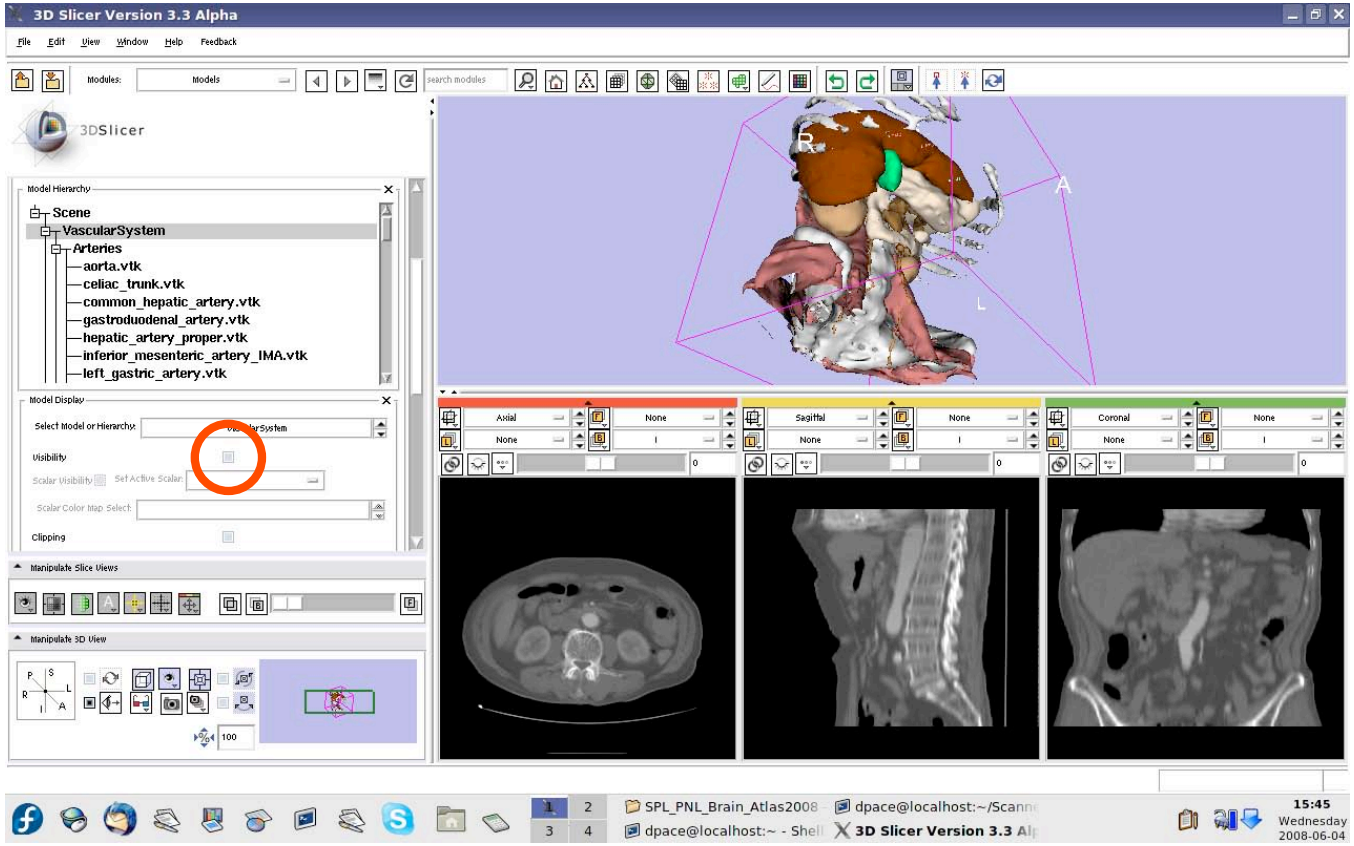
Make the models invisible

Open the Models module



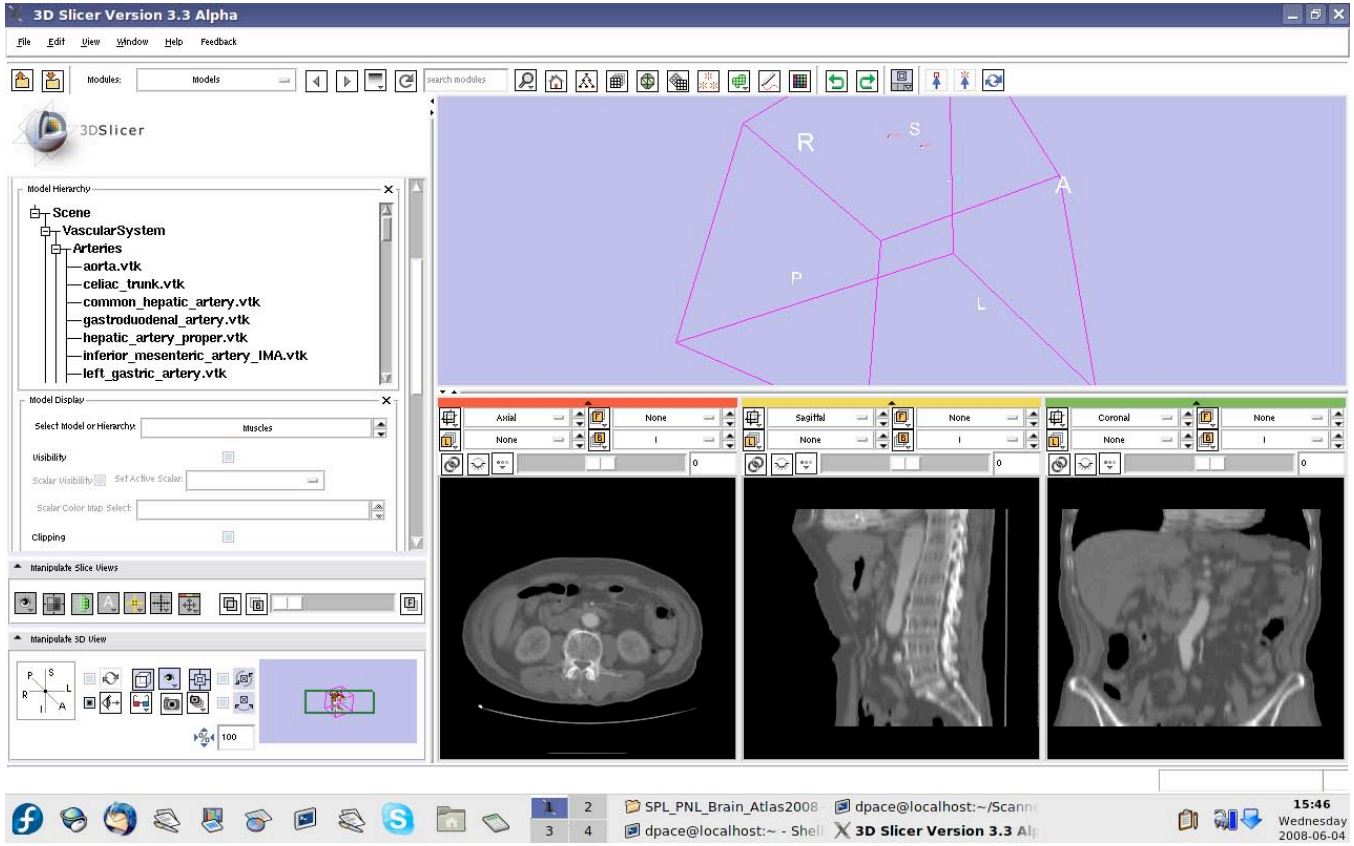
Make the models invisible

For each of the major headings in the model hierarchy, turn the visibility off



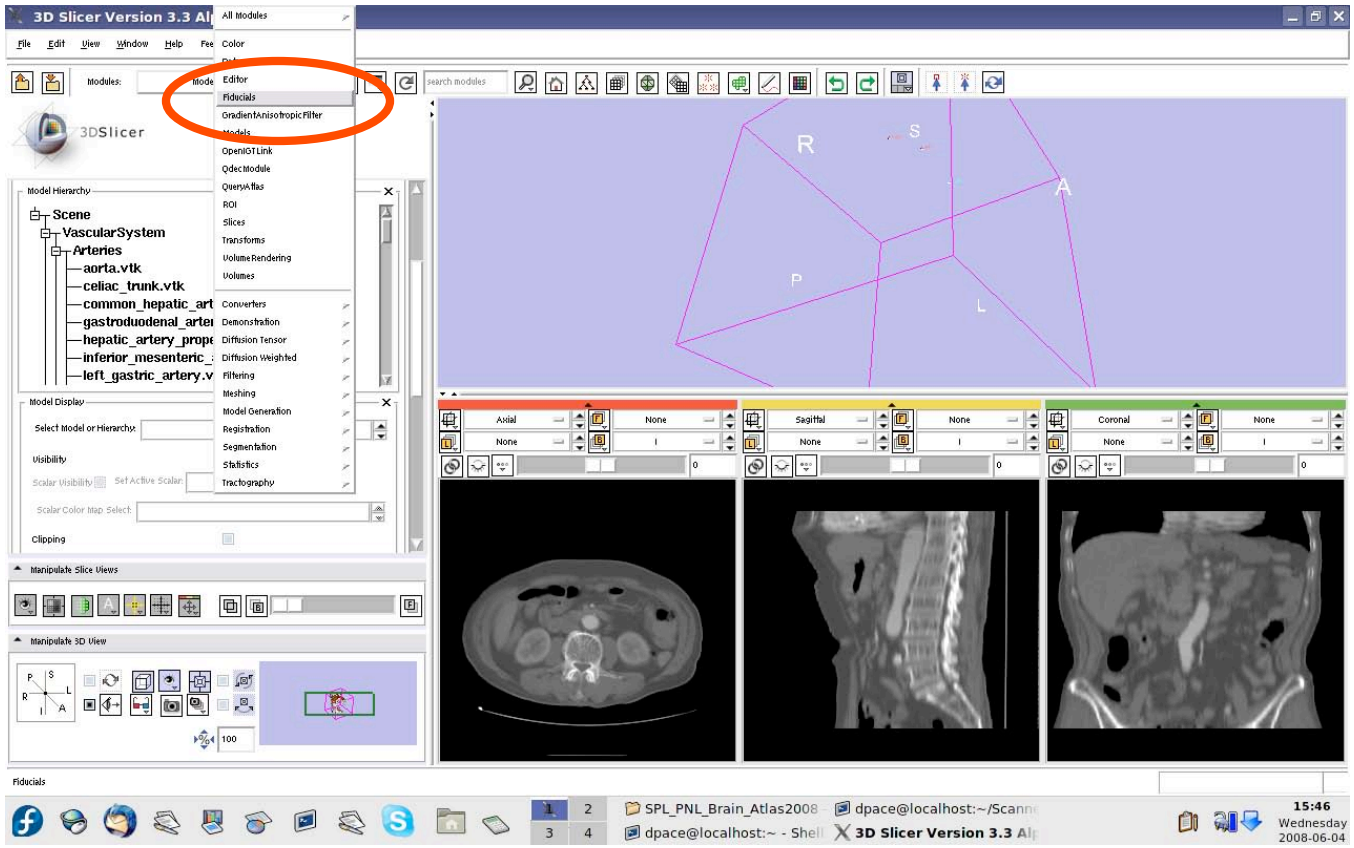
Make the models invisible

When you are finished, no models will be shown



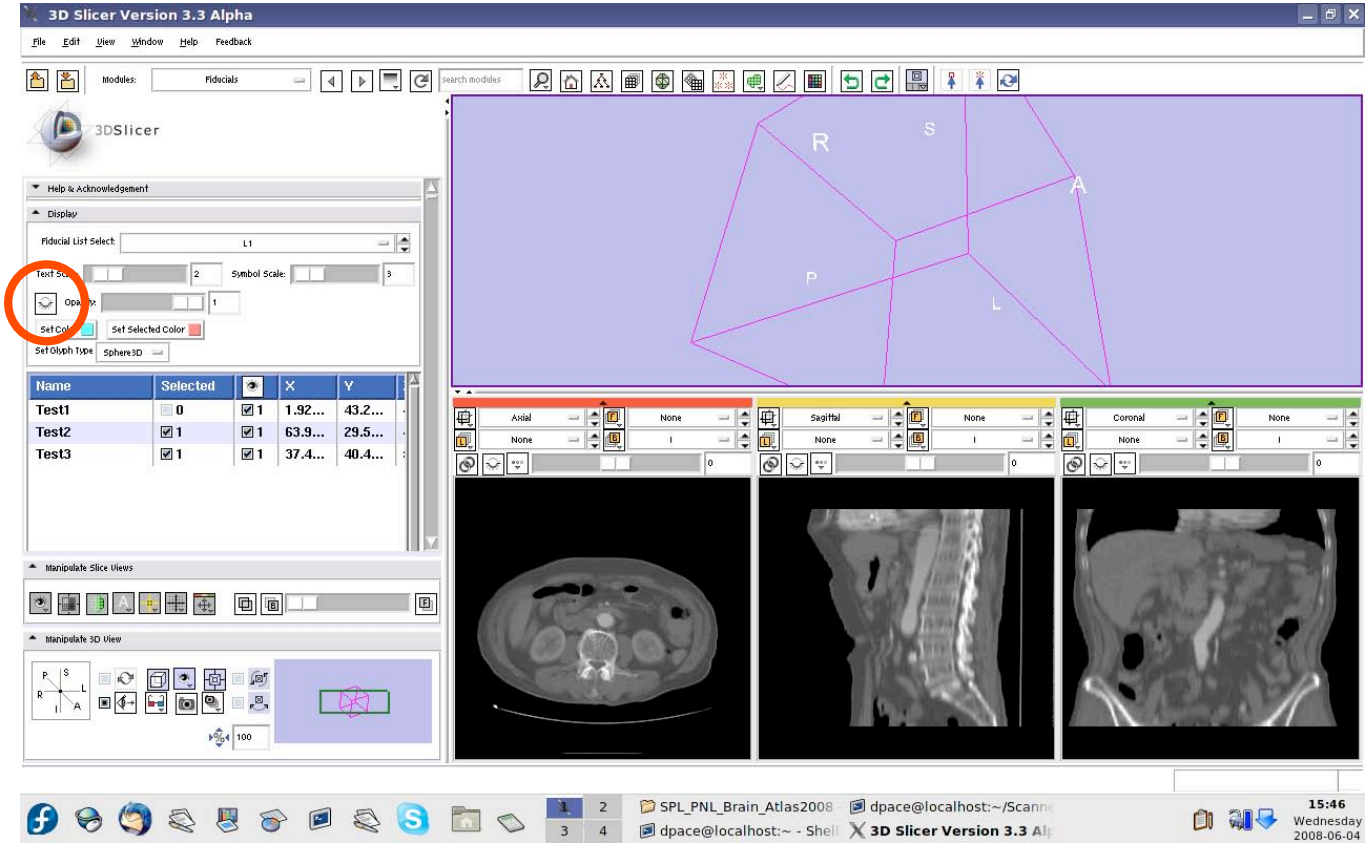
Make the fiducials invisible

If you are using the abdominal atlas, open the Fiducials module



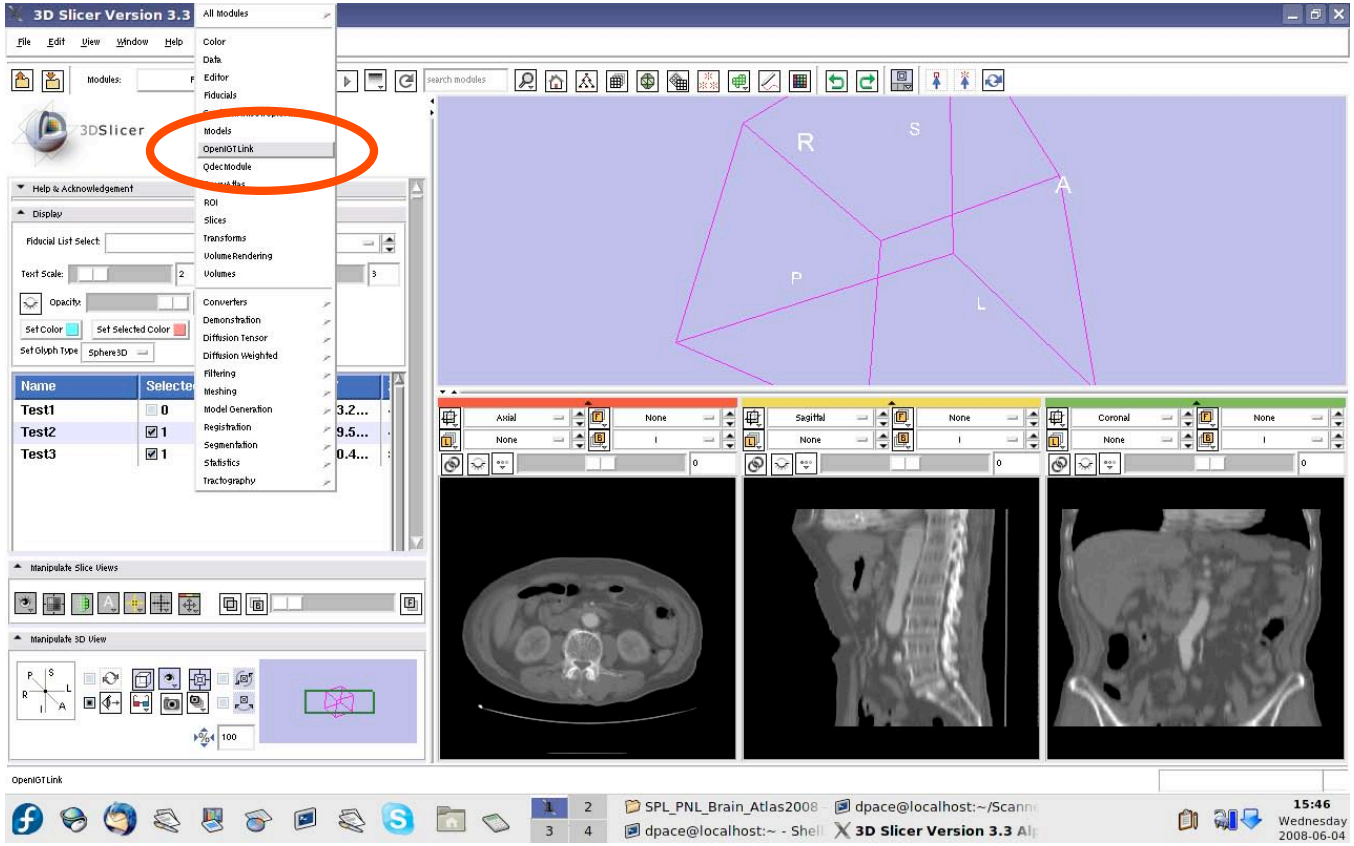
Make the fiducials invisible

If you are using the abdominal atlas, turn off the visibility of the fiducials



Set up the OpenIGTLink connection

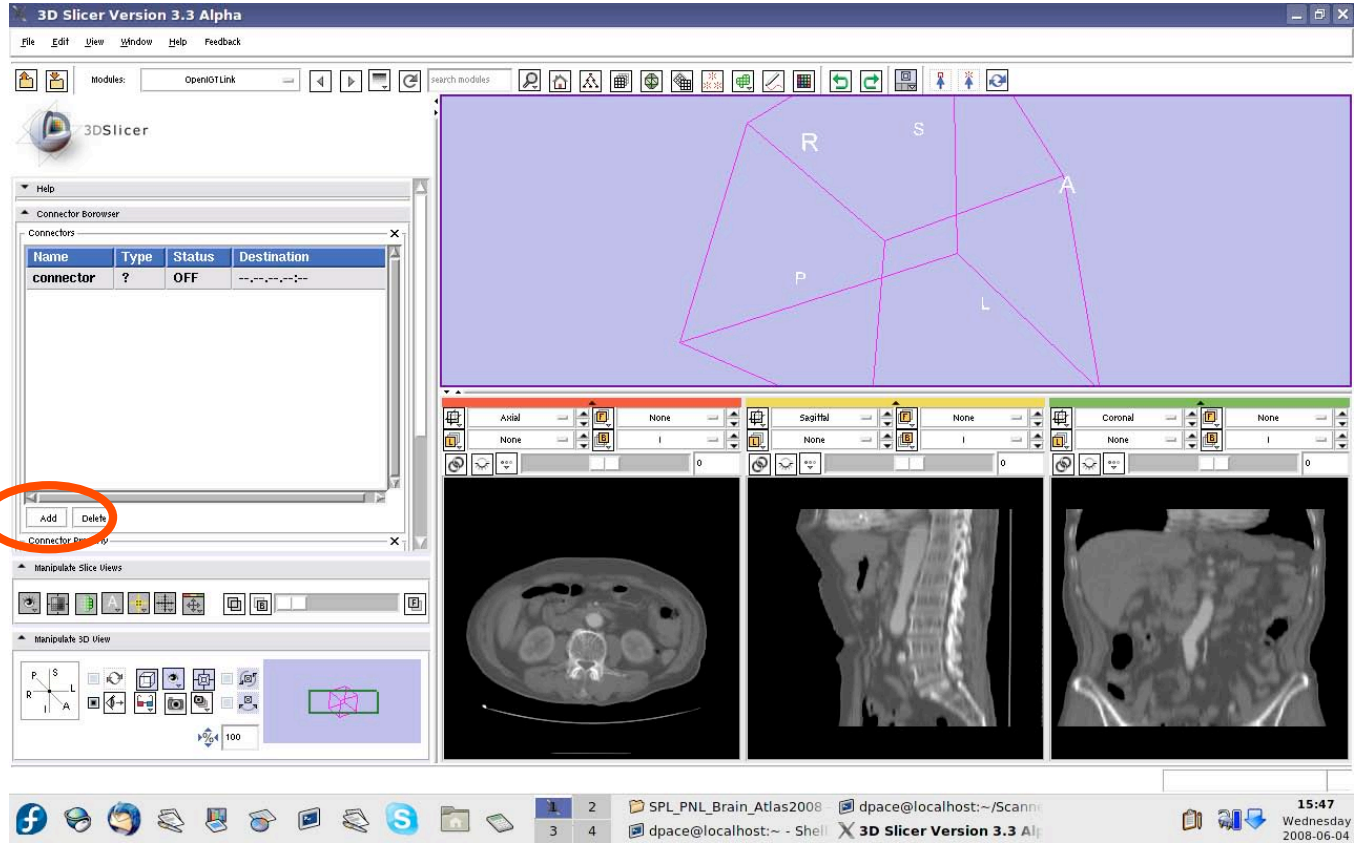
Open the OpenIGTLink module



Set up the OpenIGTLink connection

The Connectors pane shows the OpenIGTLink connections that Slicer3 is connected to

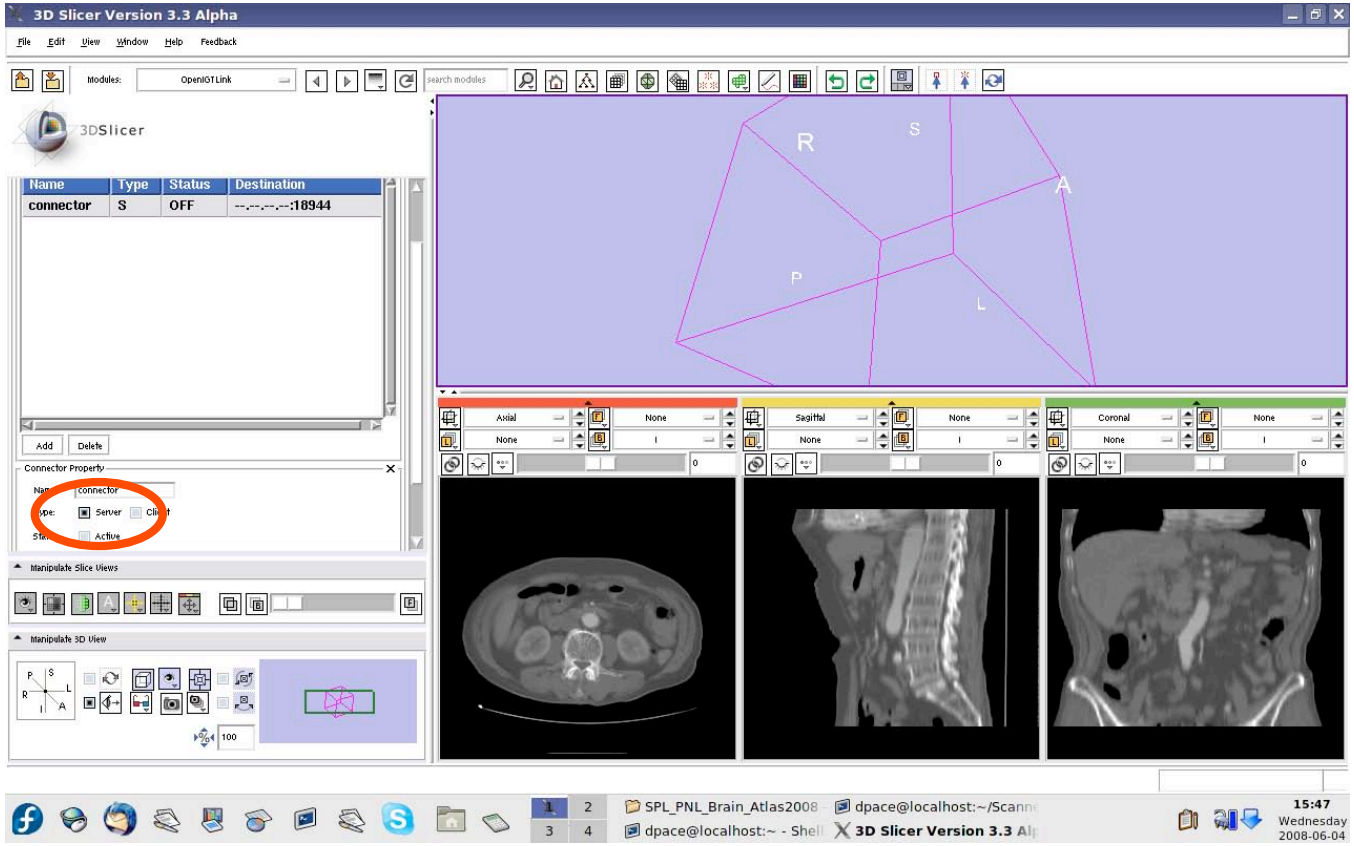
Add a new connection by clicking the “Add” button



Set up the OpenIGTLink connection

Set Slicer3 to be the server by clicking on the Server box

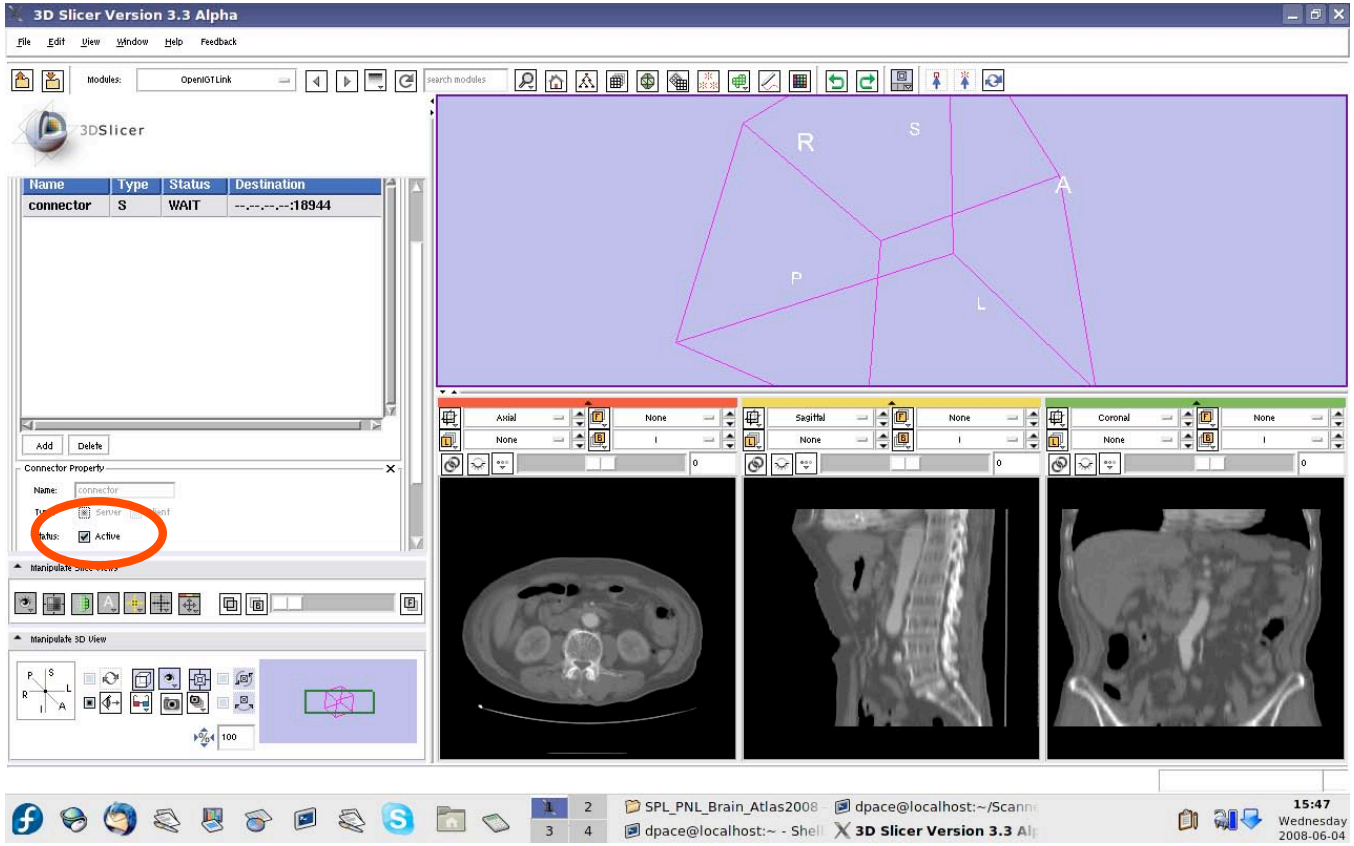
Note that the connector type is now set to "S" instead of "?"



Set up the OpenIGTLink connection

Make the connection active by clicking on the “Active” button

Note that the connector status is now set to “WAIT” instead of “OFF”

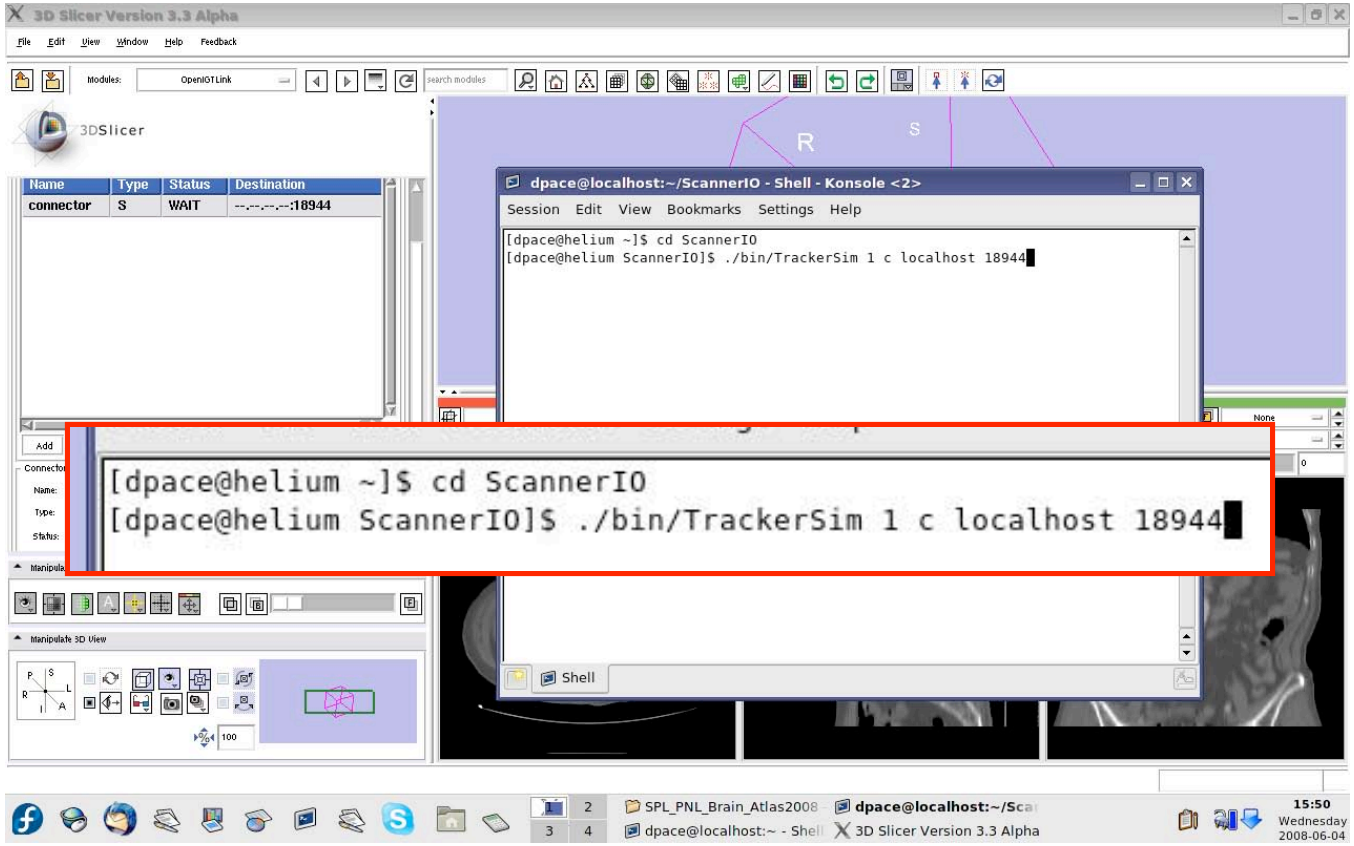


Start the tracker simulator

LINUX and MAC:

Run the TrackerSim program:

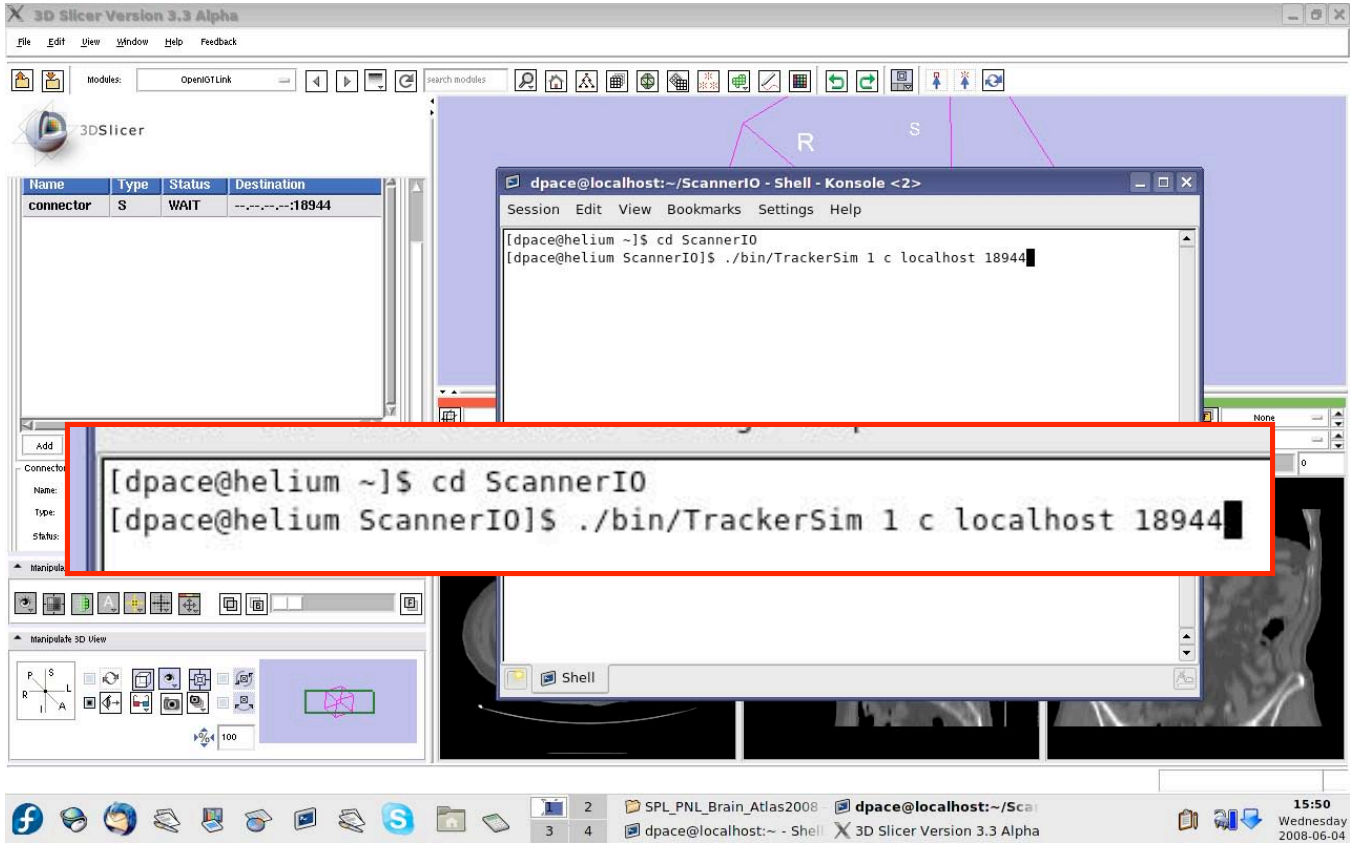
- 1 = number of frames per second
- c = TrackerSim is the client
- localhost = the host name
- 18944 = the port number



Start the tracker simulator

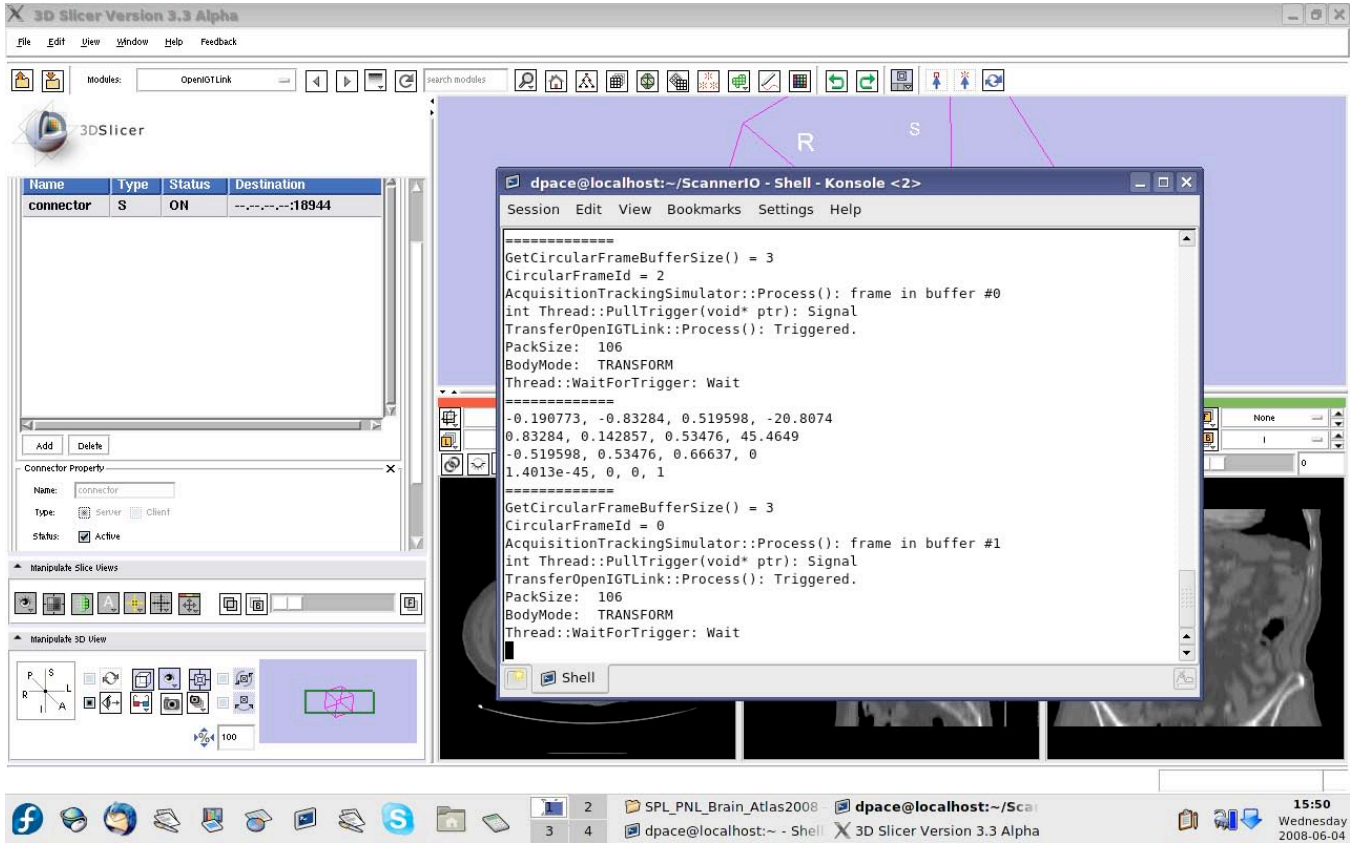
WINDOWS:

Run the RunTrackerSim program by double clicking on it



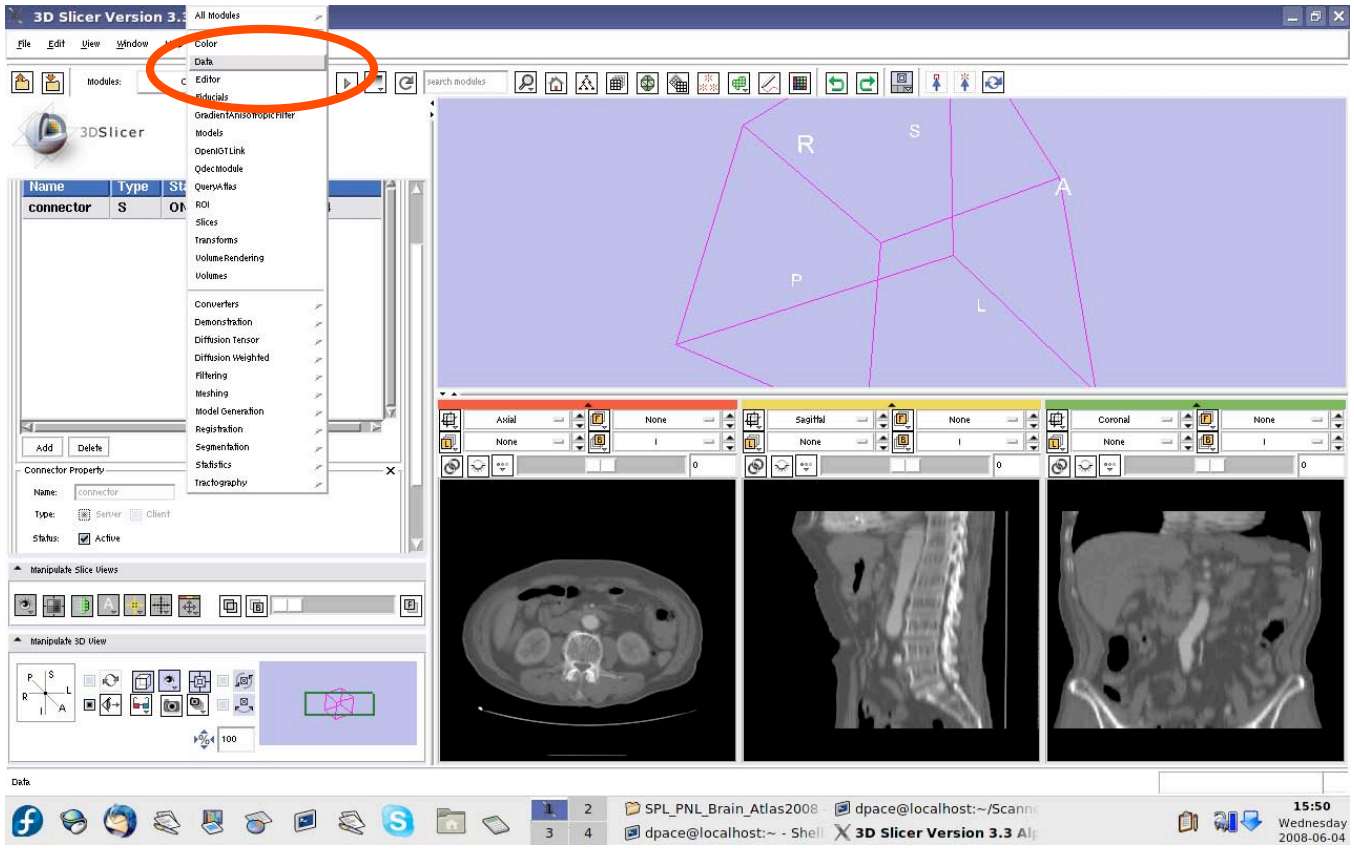
Start the tracker simulator

The transforms being sent are written to the terminal



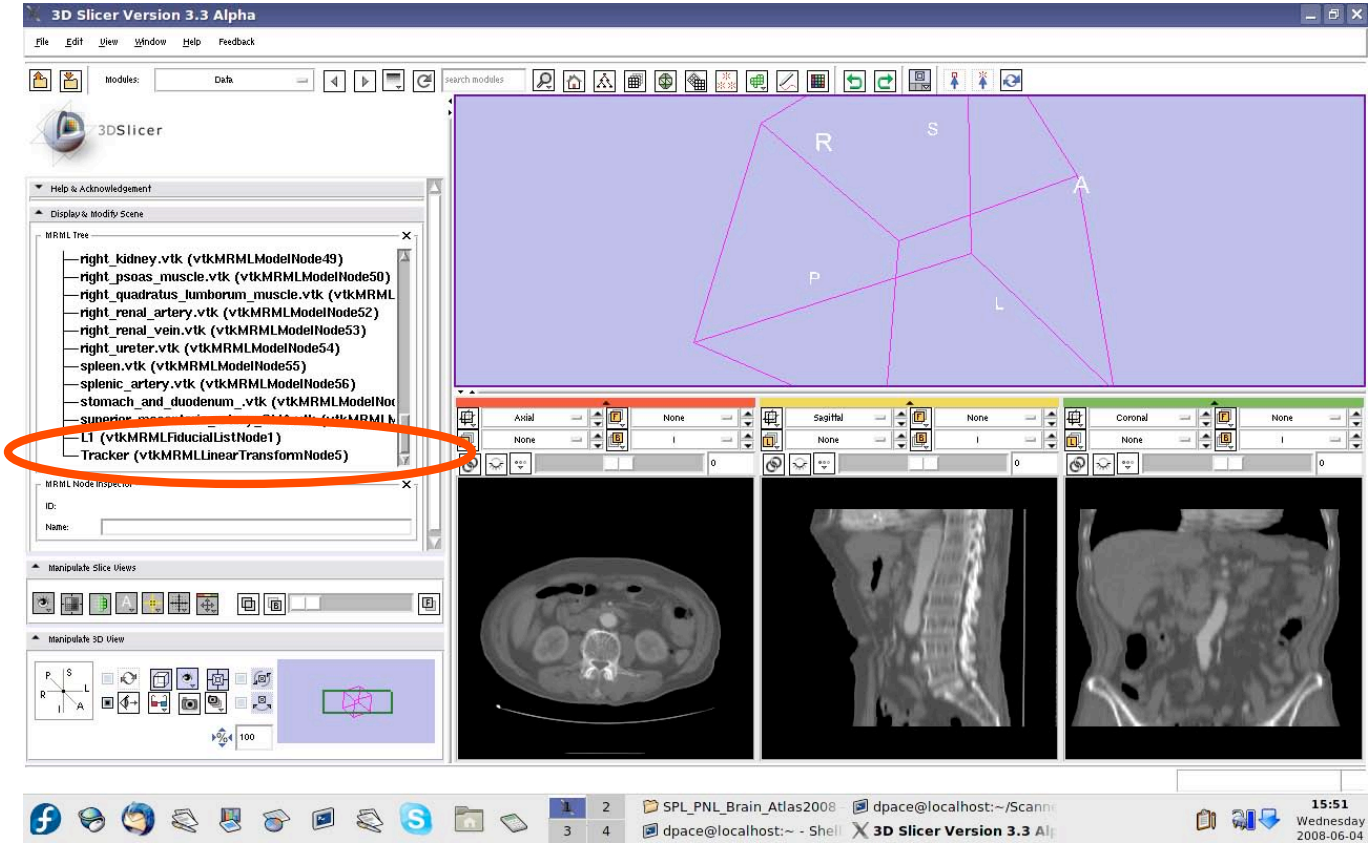
Start the tracker simulator

Open the Data module



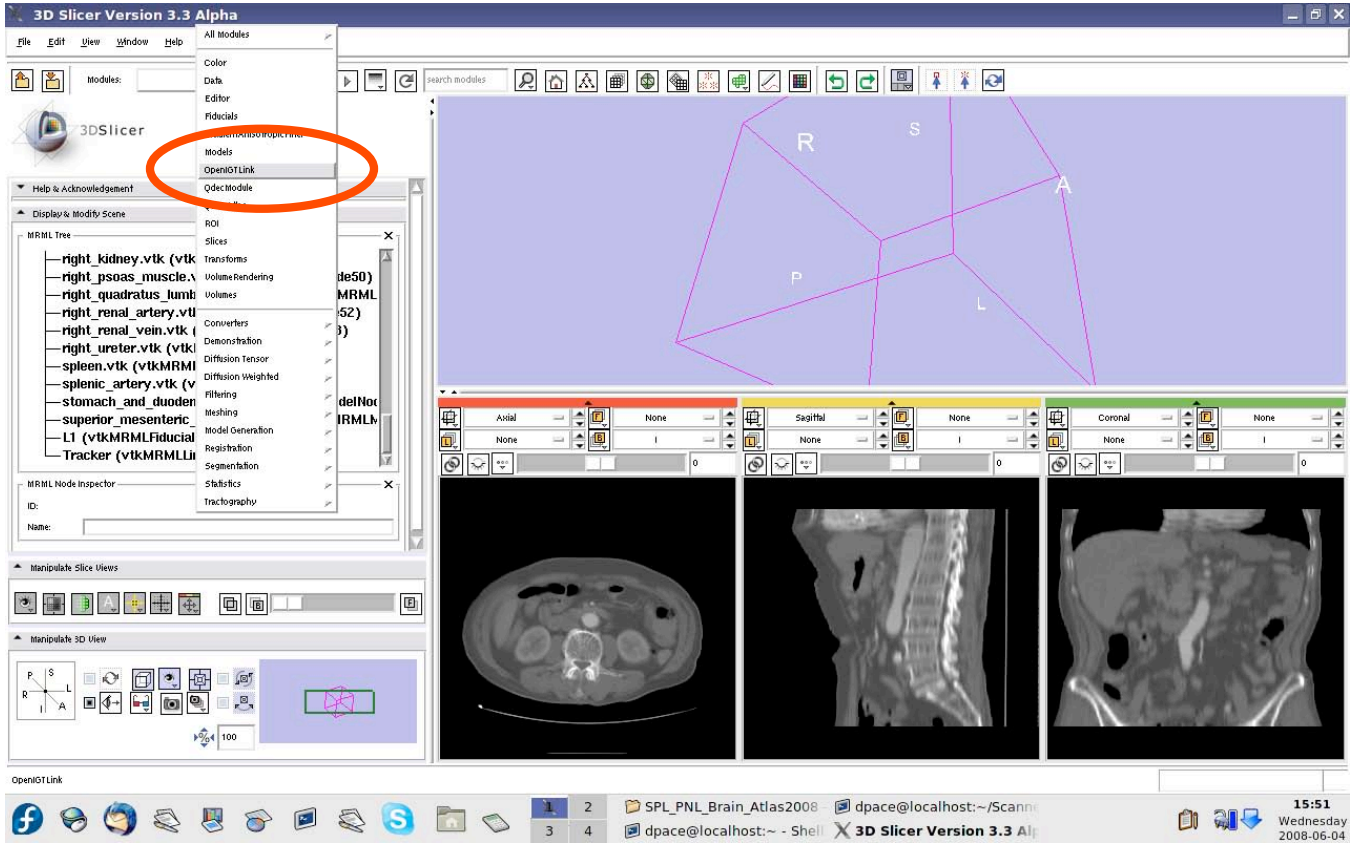
Start the tracker simulator

The new tracker node is a transform node - you can see it at the bottom of the MRML tree



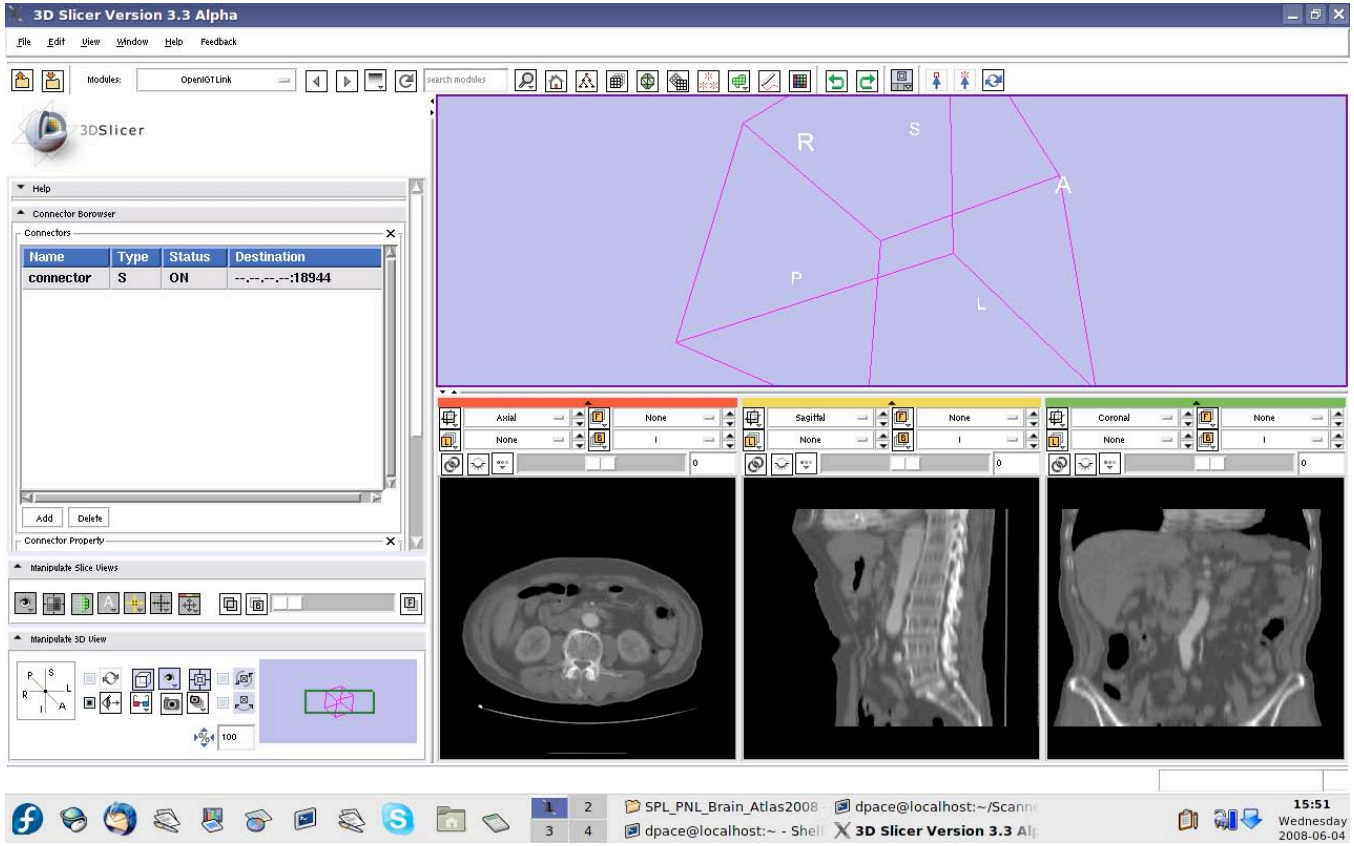
Start the tracker simulator

Open the OpenIGTLink module



Start the tracker simulator

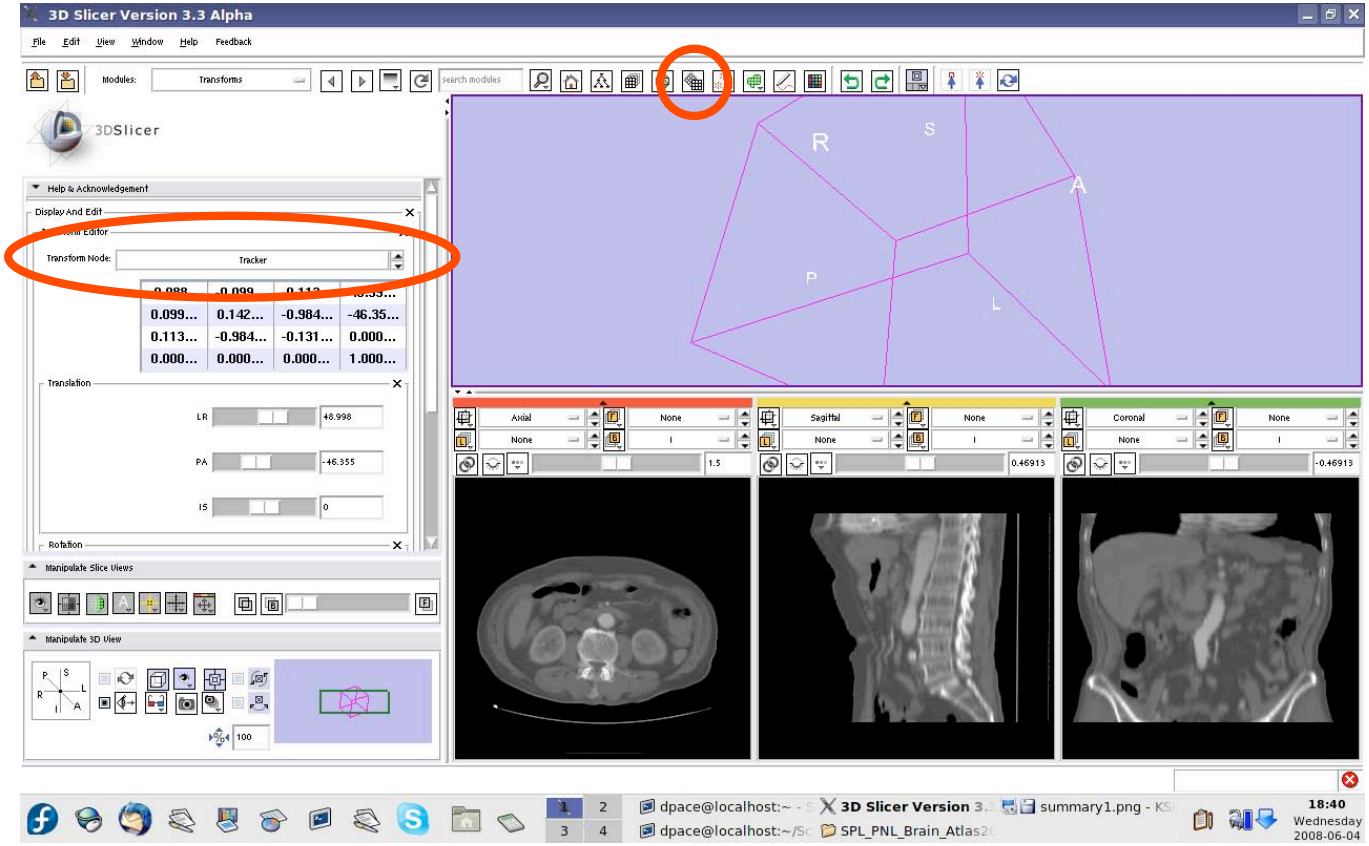
Note that the connector status is now set to “ON” instead of “WAIT”



Start the tracker simulator

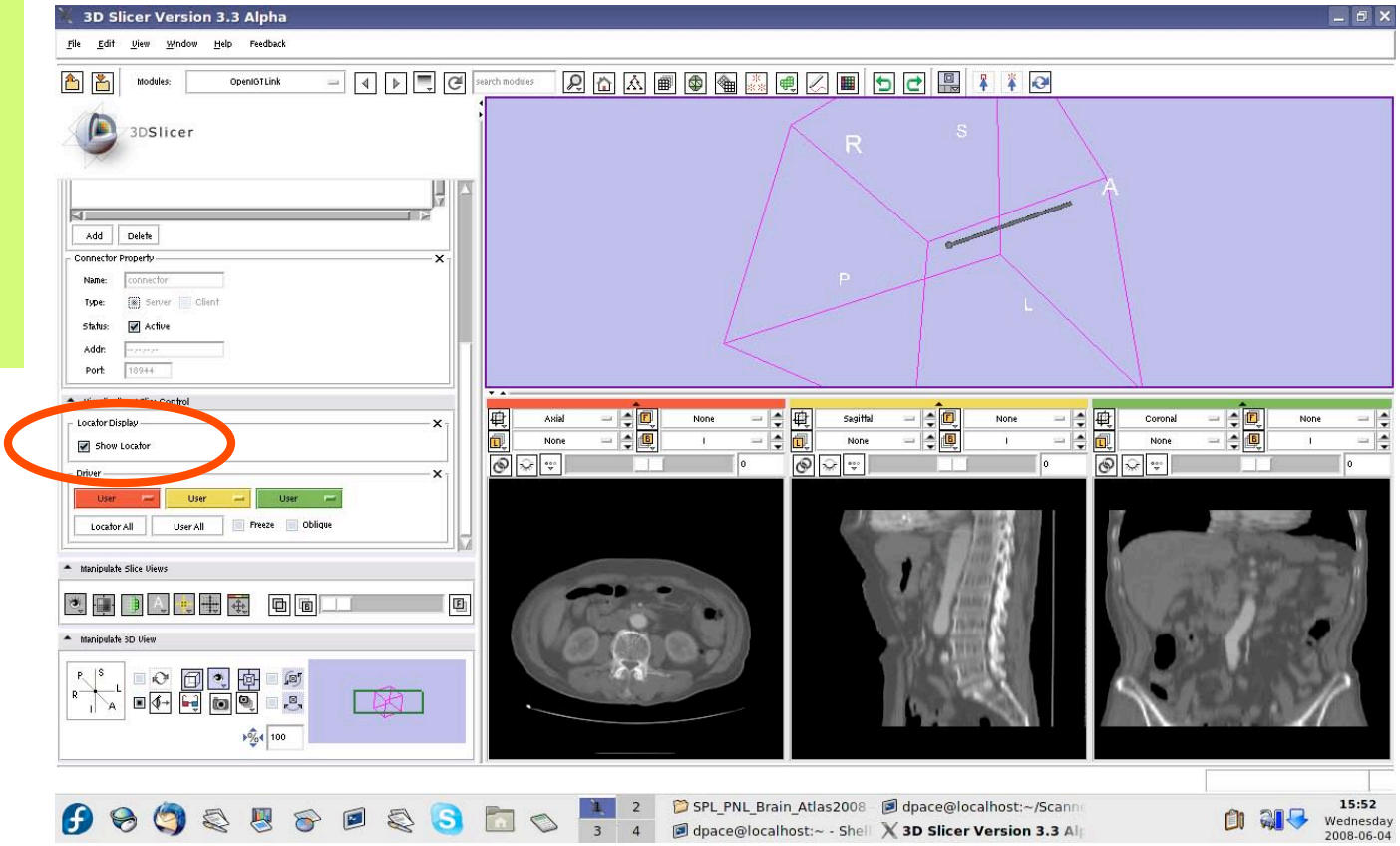
Open the Transforms module

Click on the new Tracker transform to see the changing transformation matrix



Show the transform using the locator

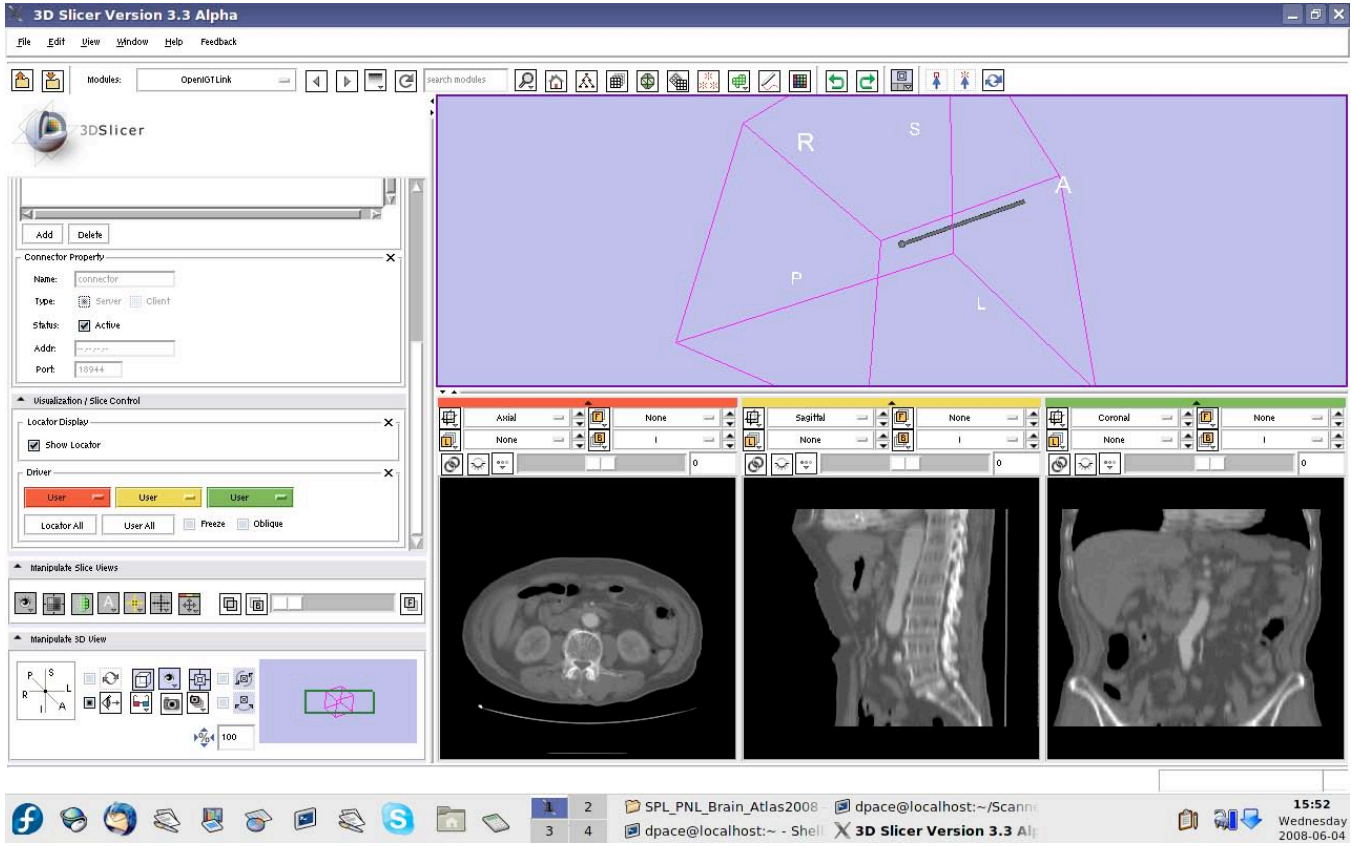
In the Visualization/ Slice Control pane, click the “Show Locator” button



If the locator does not appear, make sure that the IGTLocator model is set to “visible” in the Models module

Show the transform using the locator

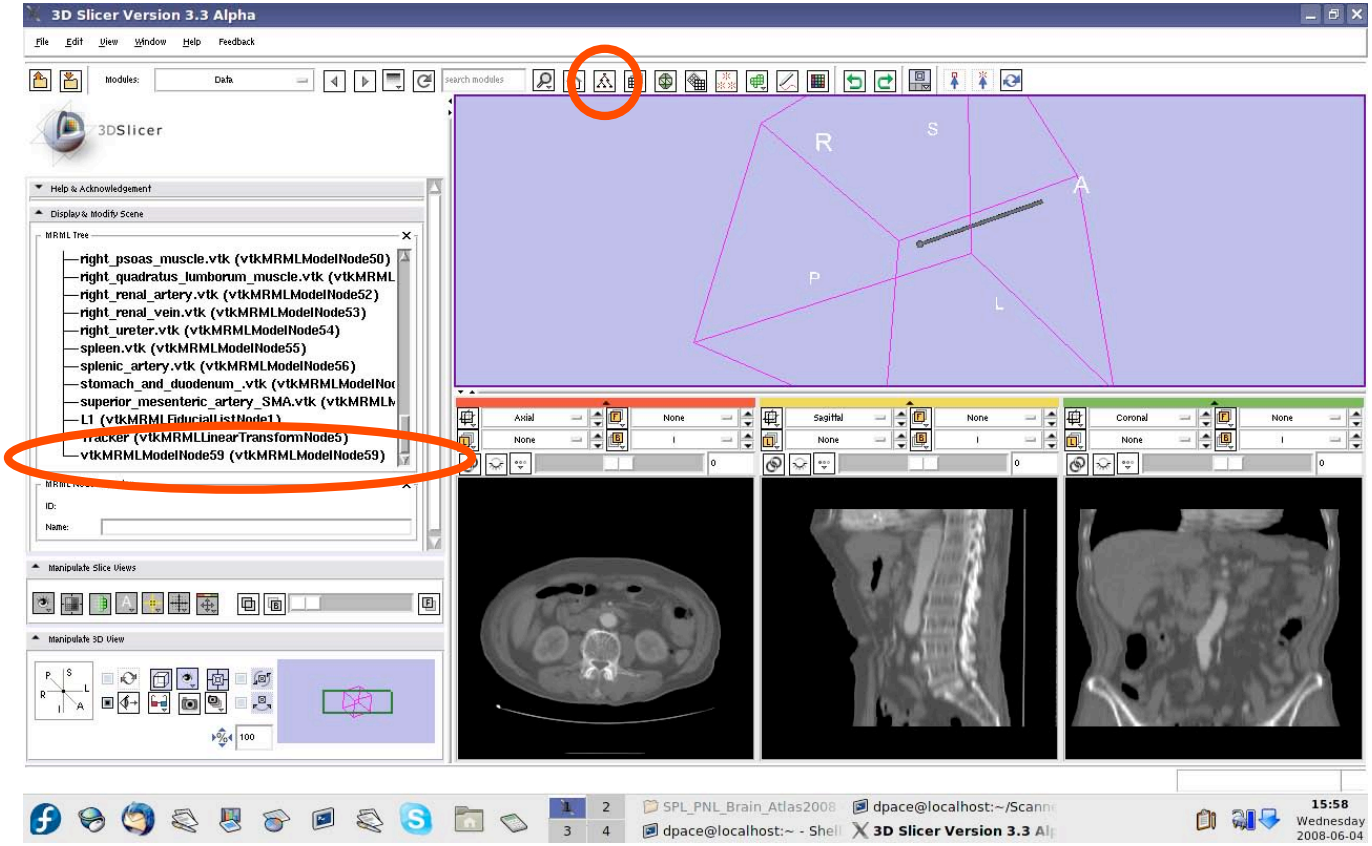
The round end shows the simulated tool's position, and the cylinder shows the simulated tool's orientation



Show the transform using the locator

Open the Data module

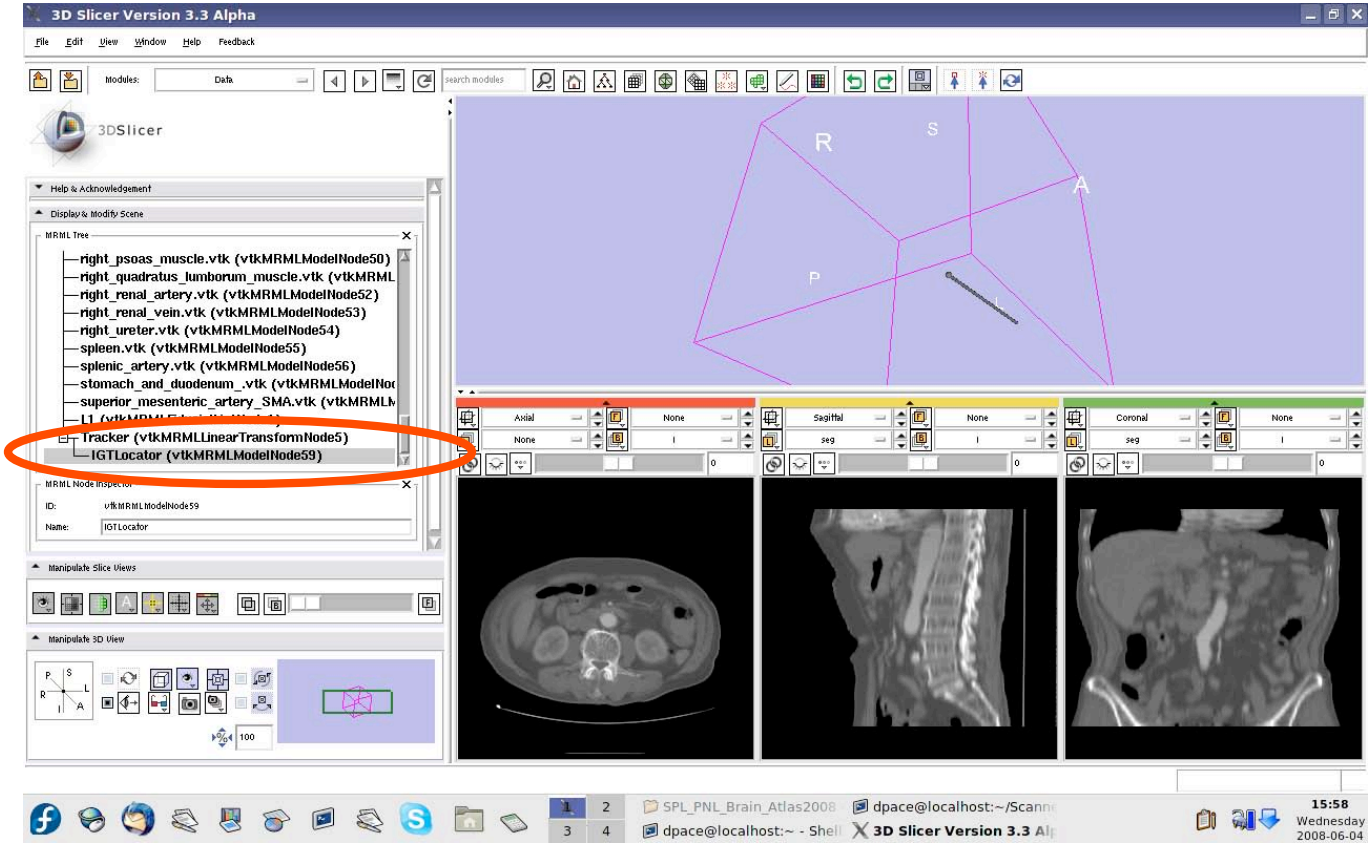
The new locator node is a model node at the bottom of the MRML tree



Show the transform using the locator

Drag the locator node under the Tracker node

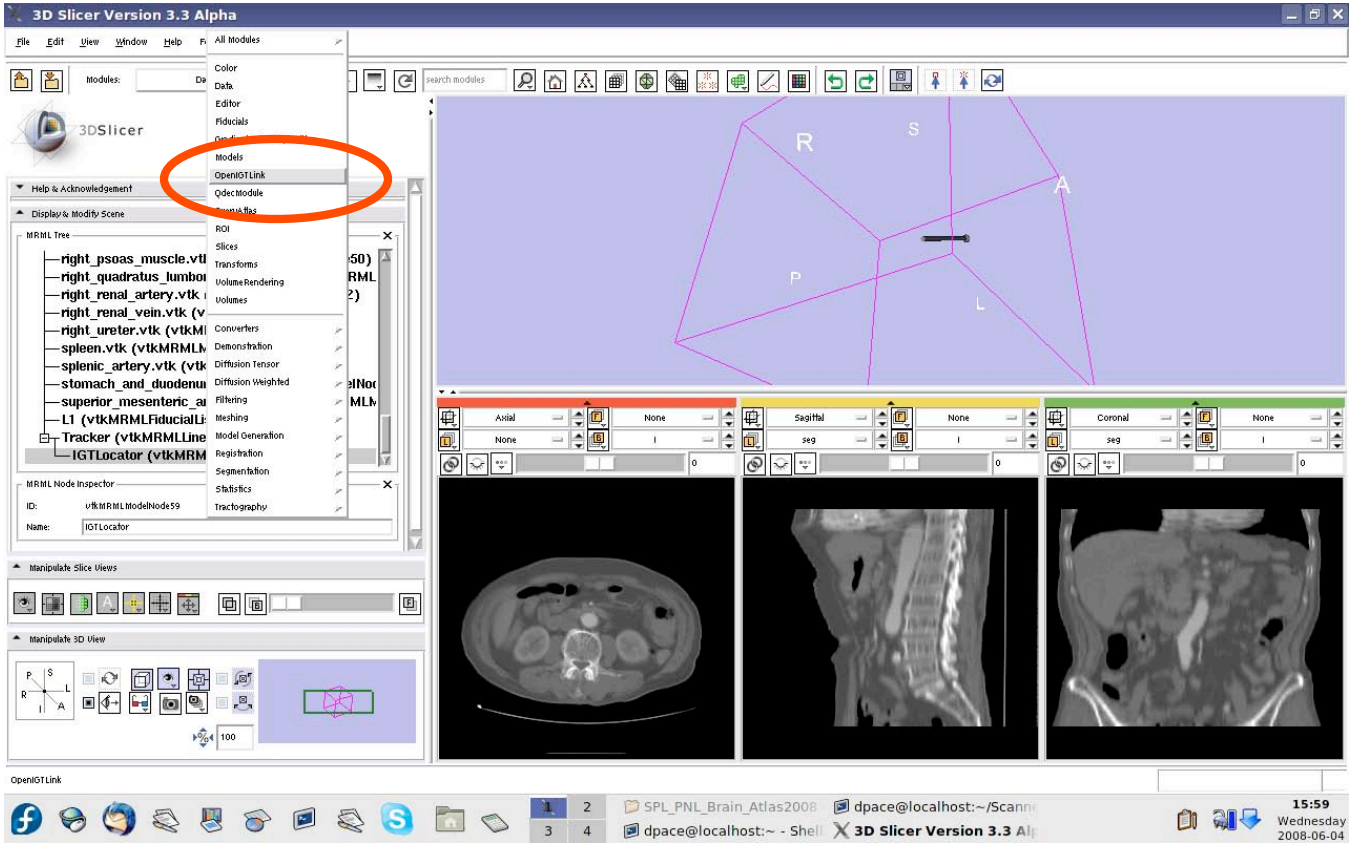
The Tracker transform is now applied to the locator model - it will move according to the transforms from the tracker simulator



Show the transform using a model

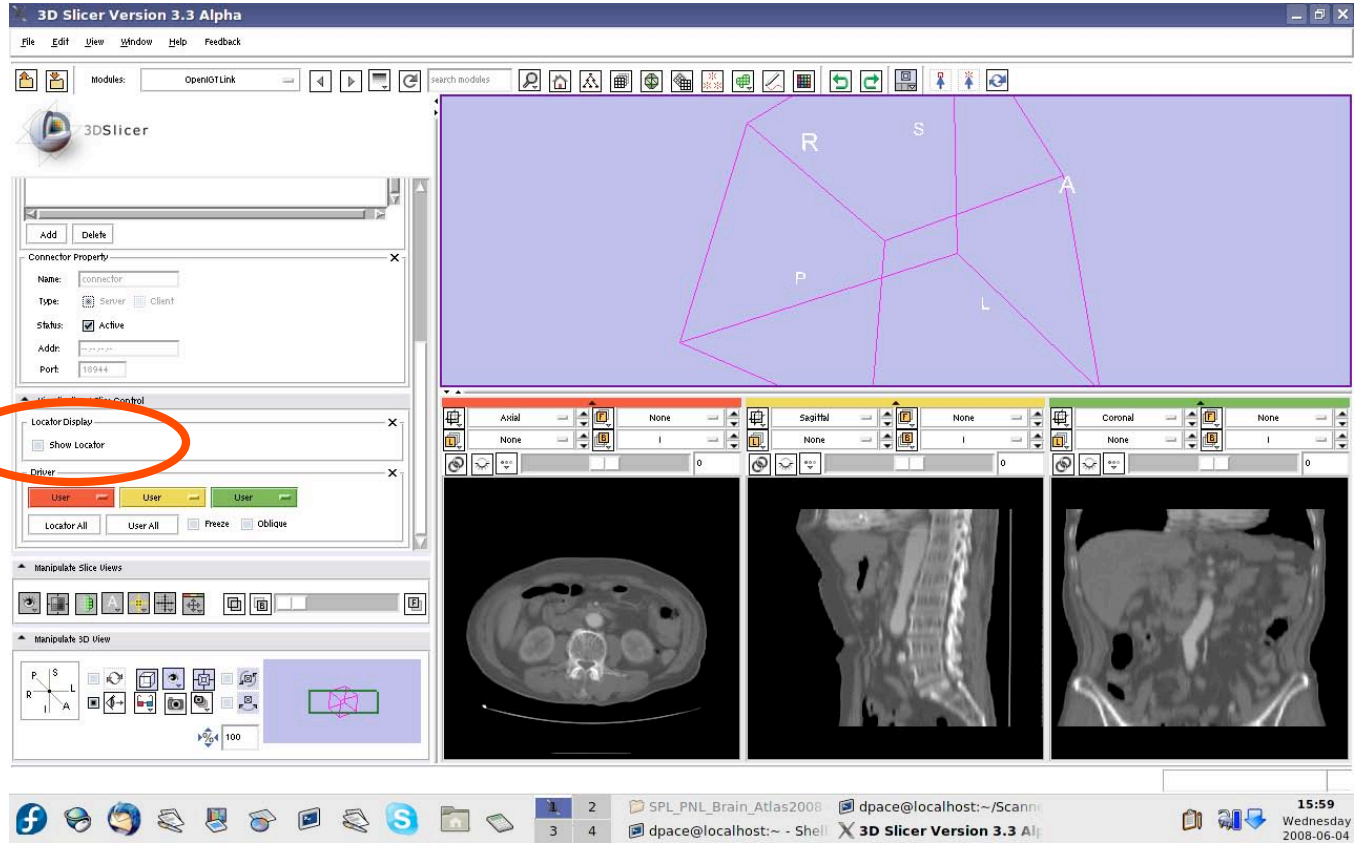
Other objects, such as models or images, can be moved according to the tracking transforms

Open the OpenIGTLink module



Show the transform using a model

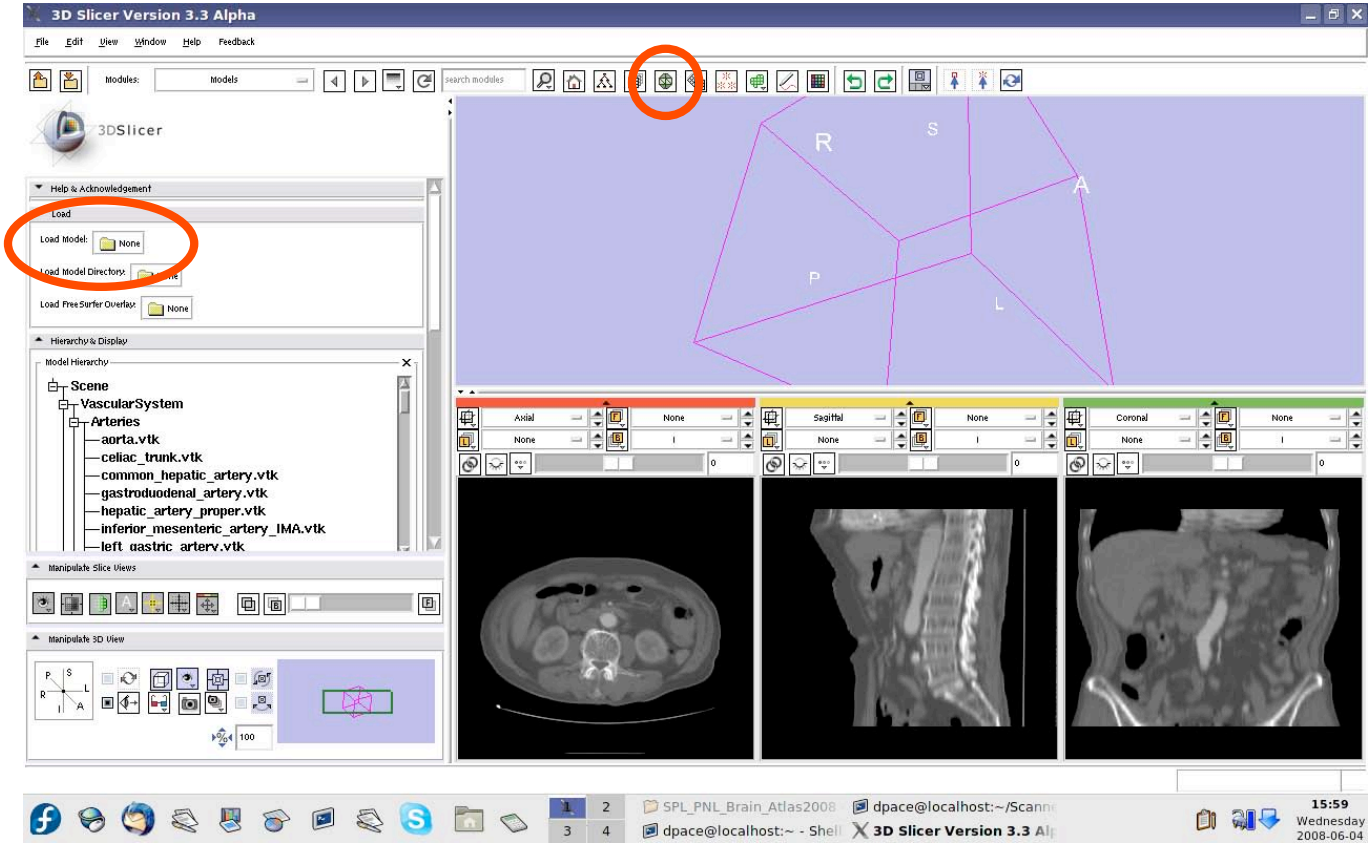
In the Visualization/ Slice Control pane, turn off the locator



Show the transform using a model

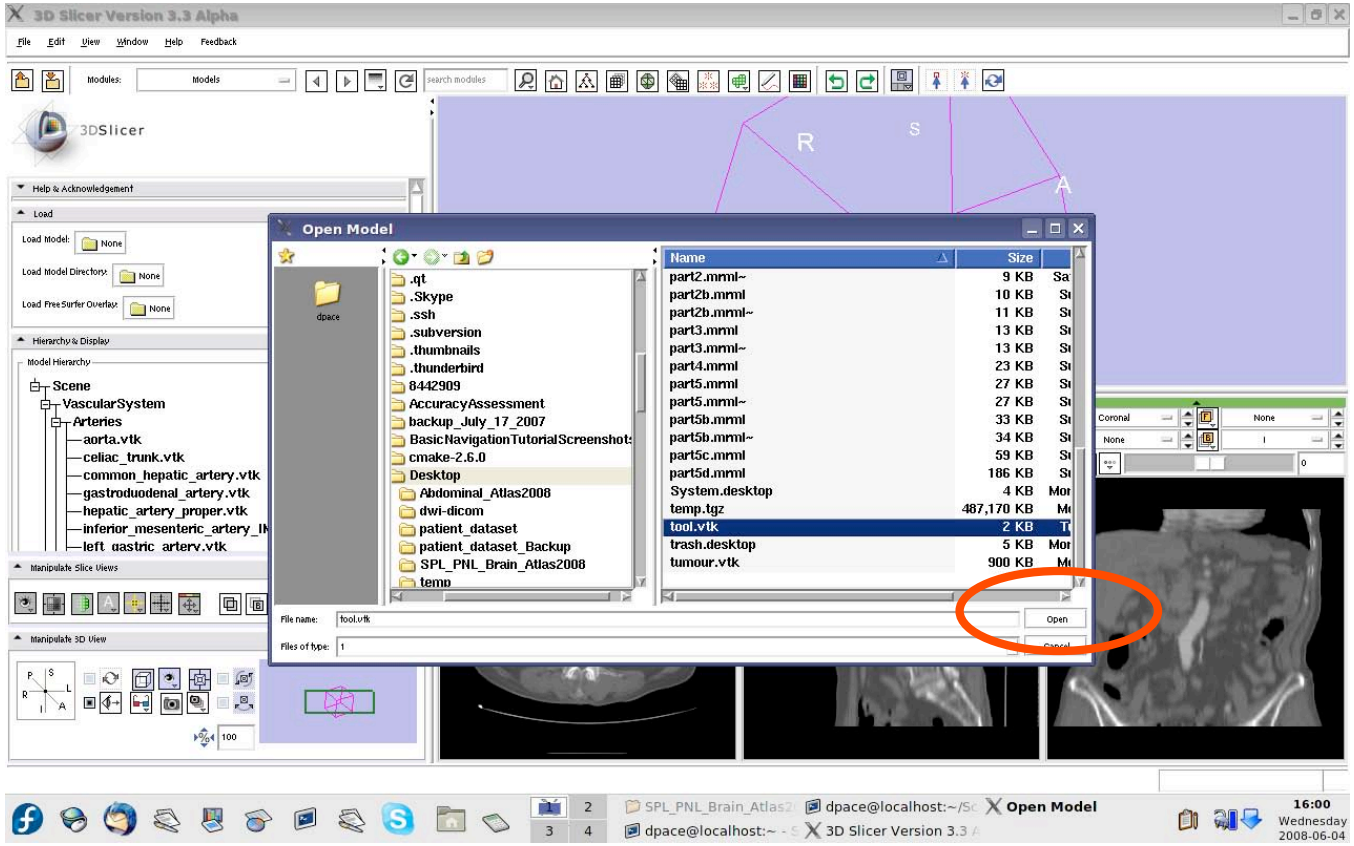
Open the Models module

Click on the folder icon to load a model



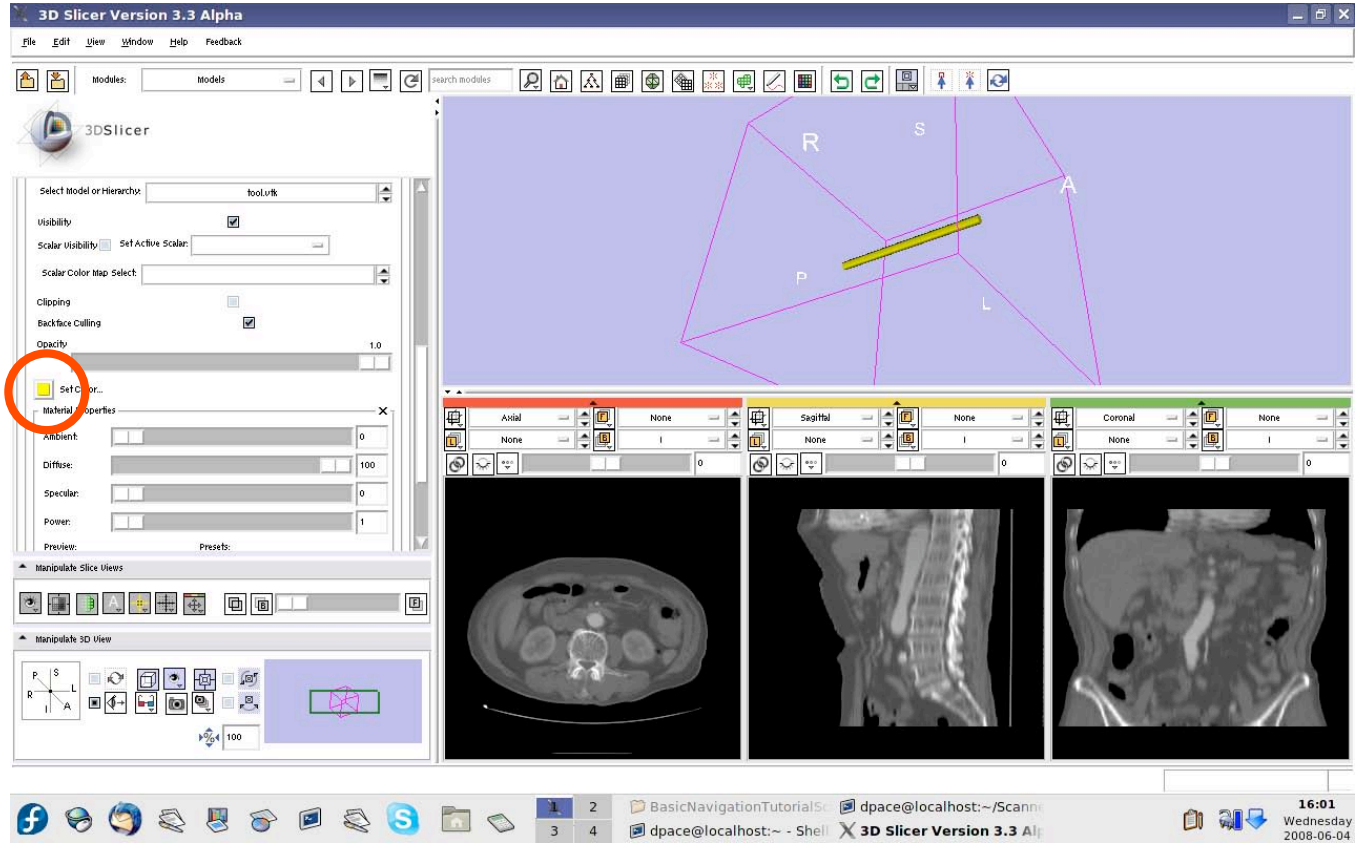
Show the transform using a model

Click on tool.vtk and then click “Open”



Show the transform using a model

In the Models module, change the colour of the model to yellow

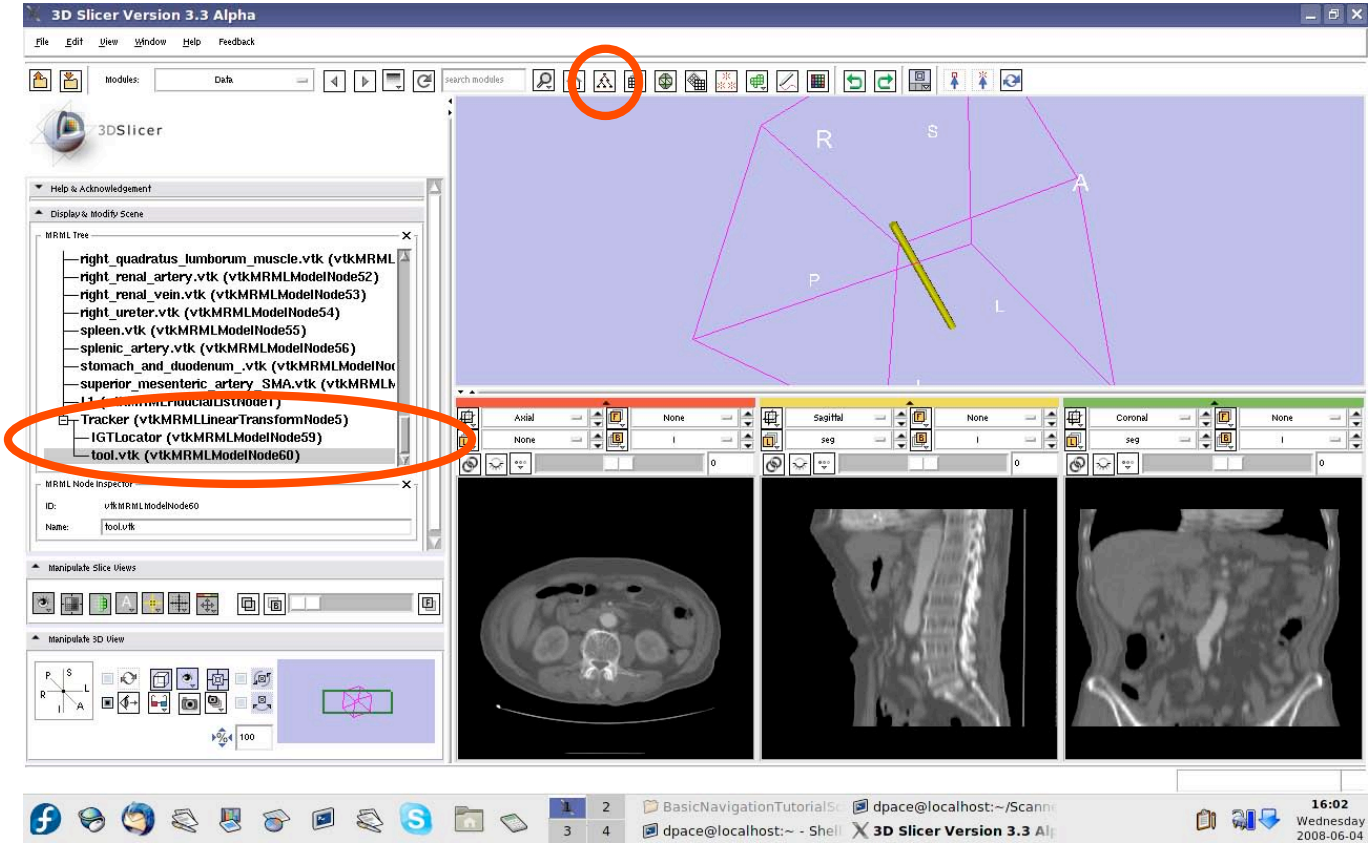


Show the transform using a model

Open the Data module

Drag the tool.vtk node under the Tracker node

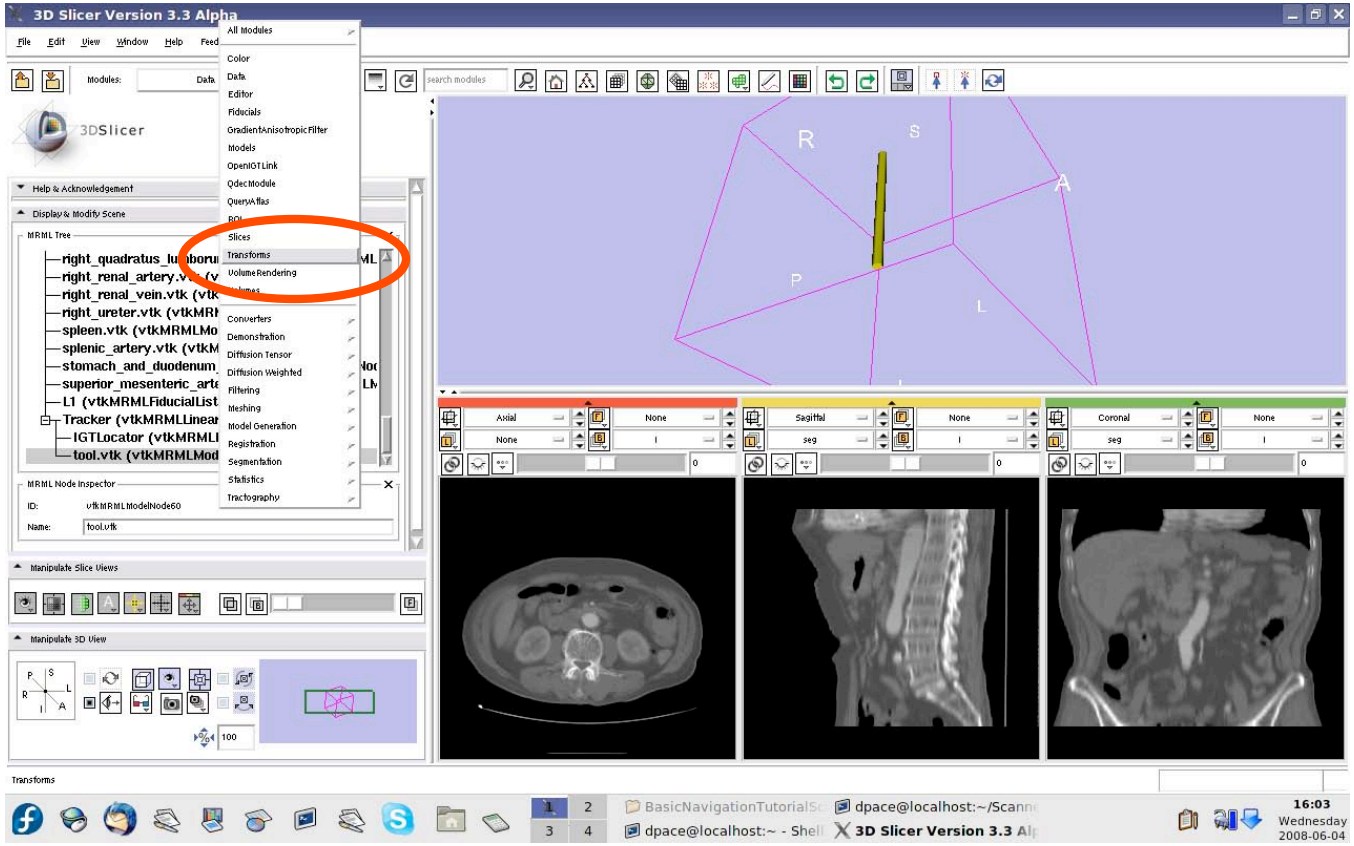
The Tracker transform is now applied to the tool model - it will move according to the transforms from the tracker simulator



Add a calibration matrix

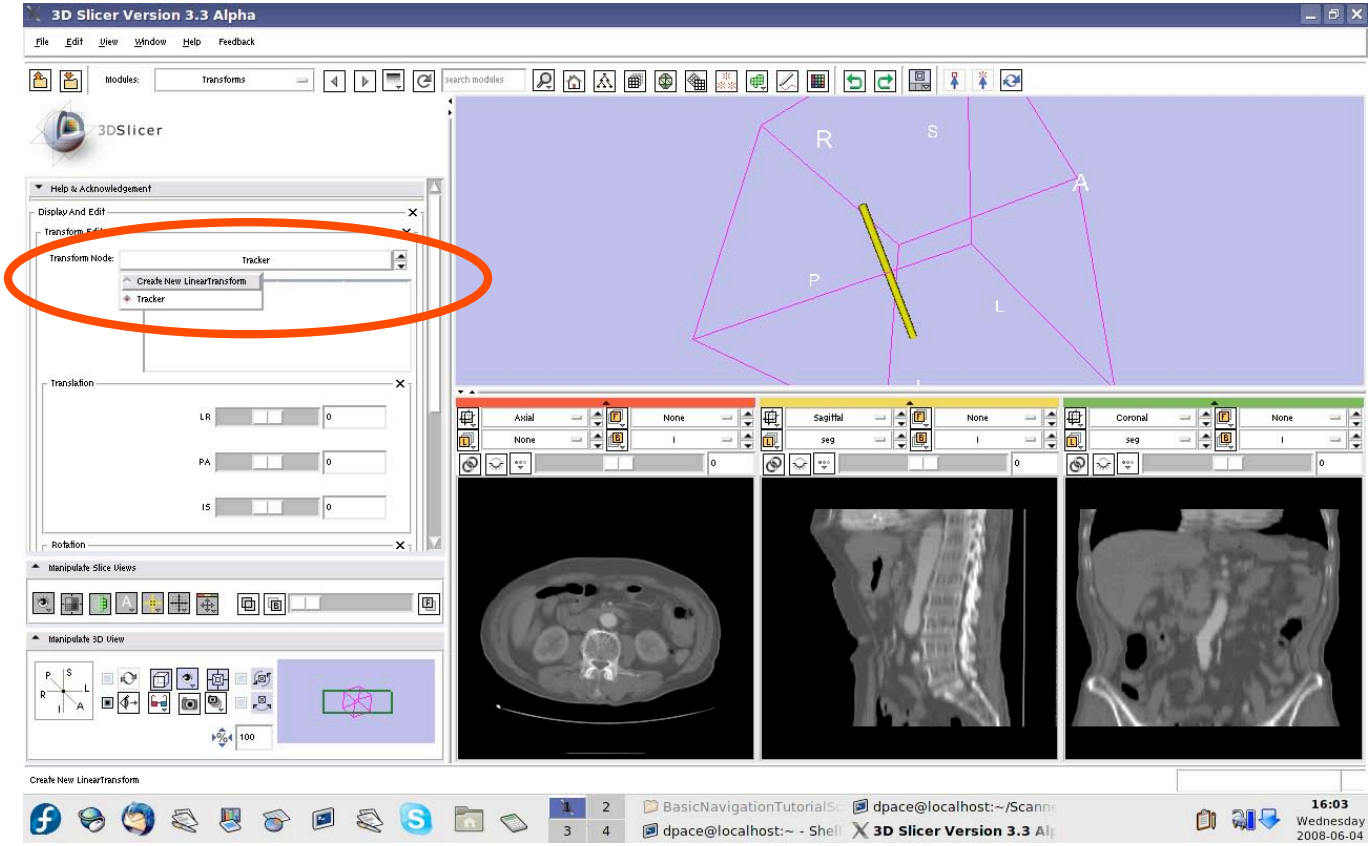
Transforms can be multiplied together - we will incorporate an additional translation

Open the Transforms module



Add a calibration matrix

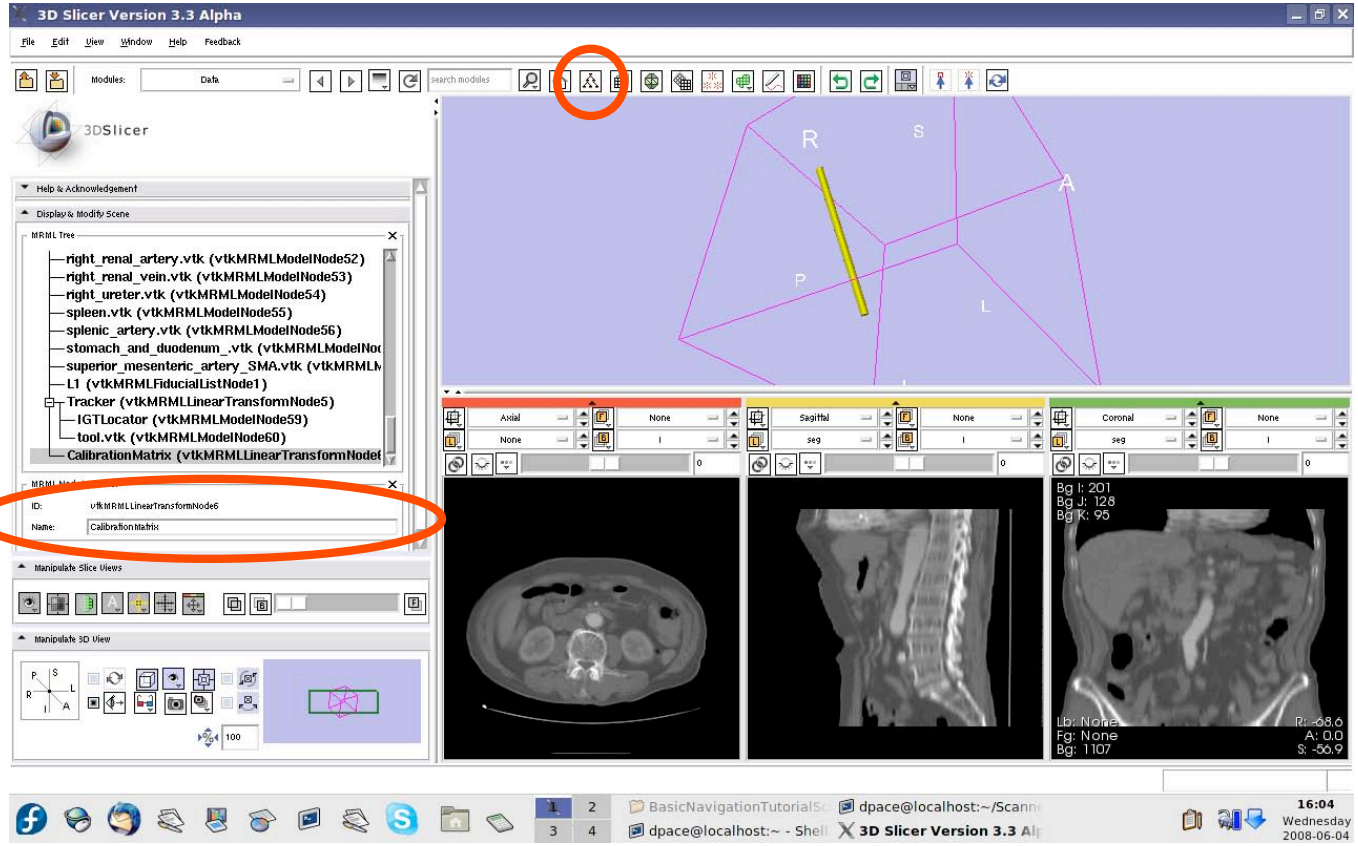
Add a new transform node



Add a calibration matrix

Open the Data module

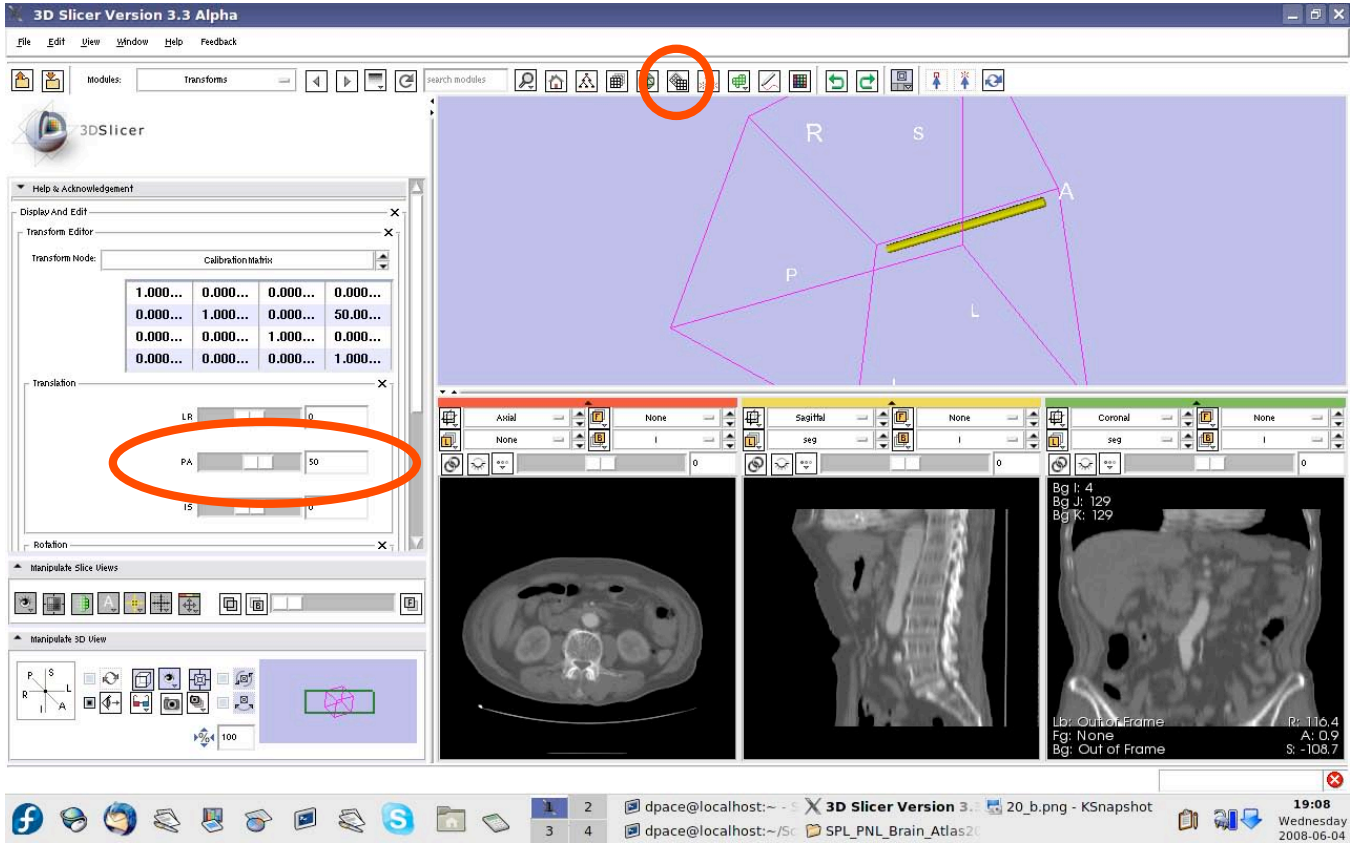
Rename the new transform to “Calibration Matrix” by selecting it and then changing the name in the MRML node inspector



Add a calibration matrix

Open the Transforms module

Set the PA (posterior-anterior) translation to 50

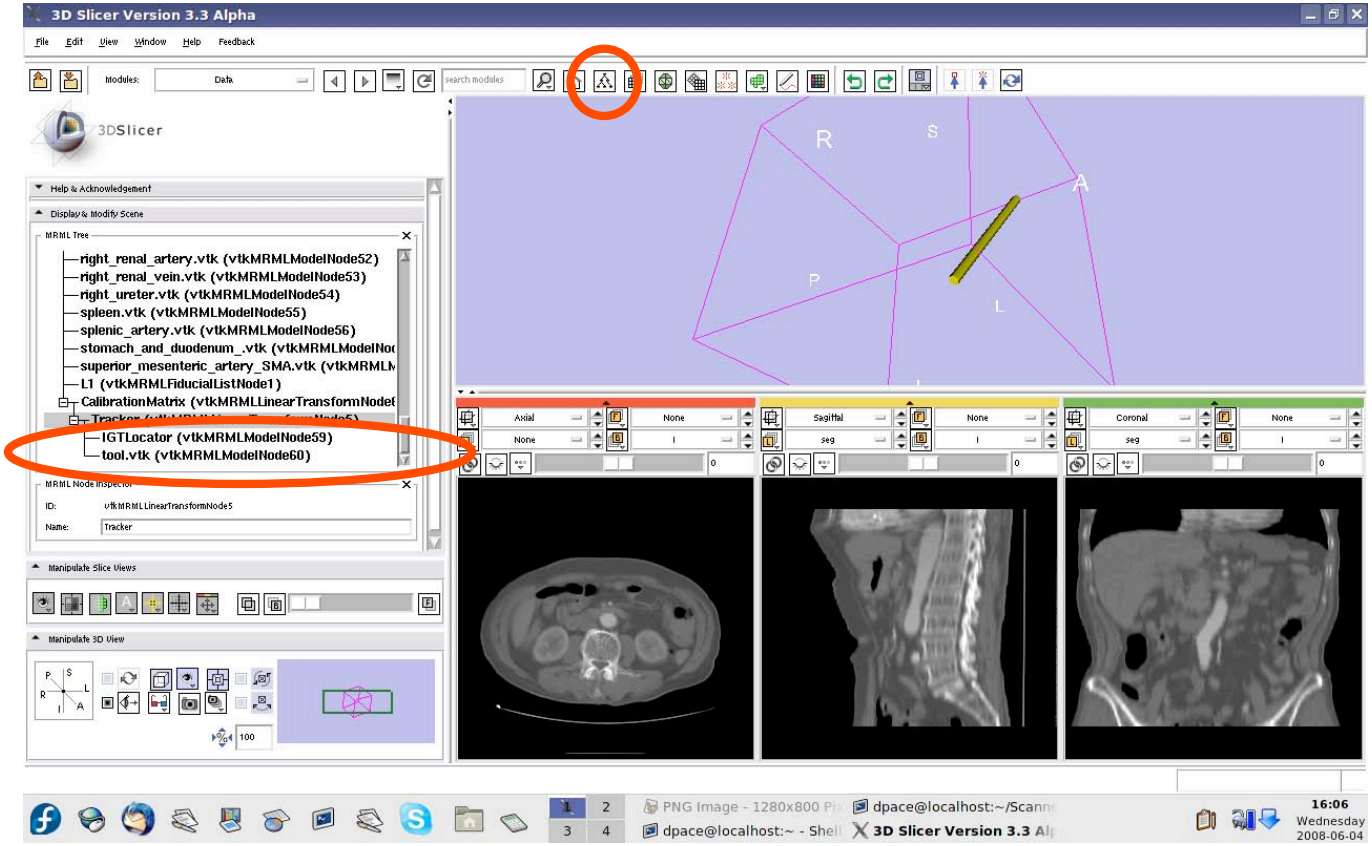


Add a calibration matrix

Open the Data module

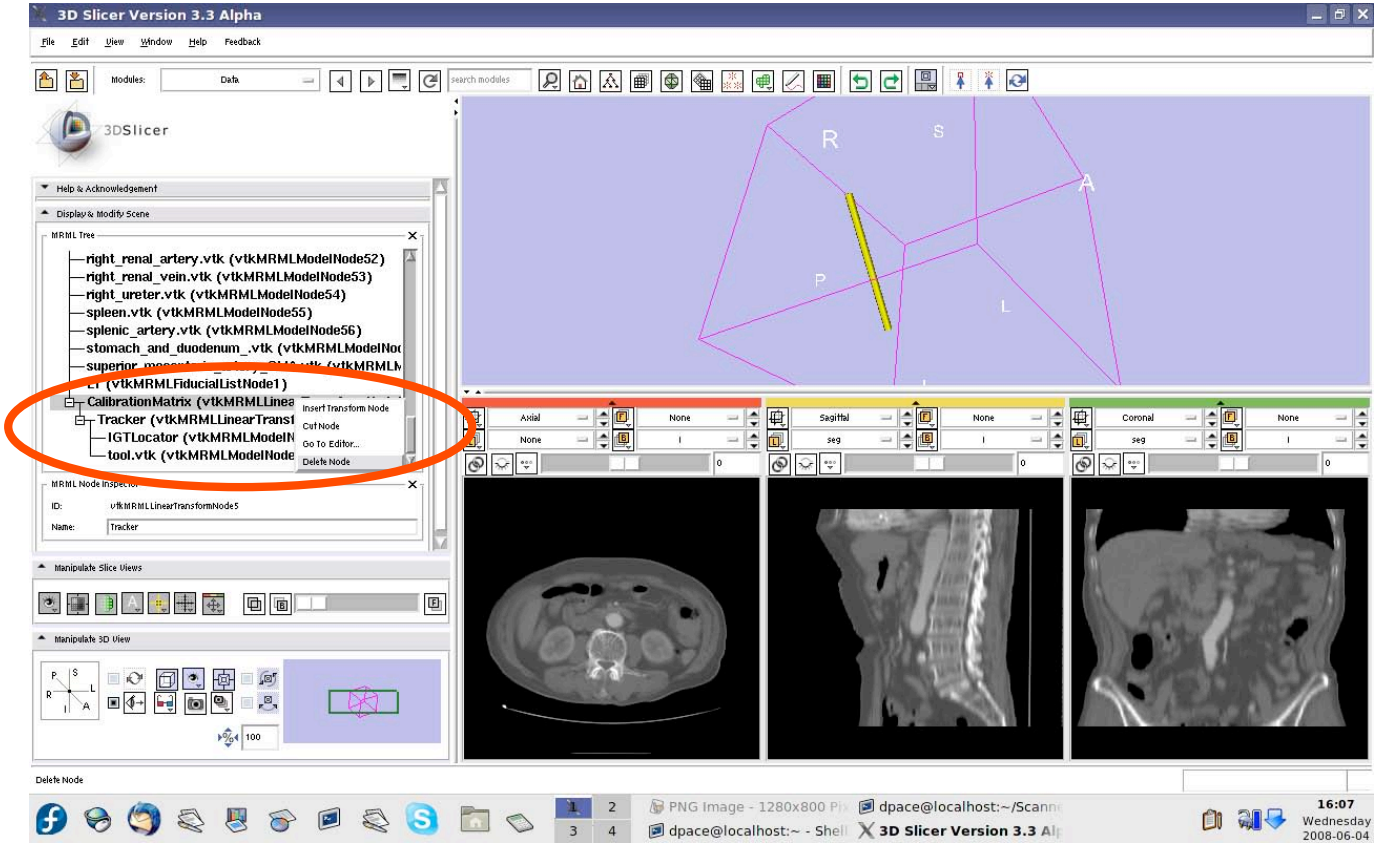
Drag the Tracker node under the Calibration Matrix node

The model will be translated along its length axis



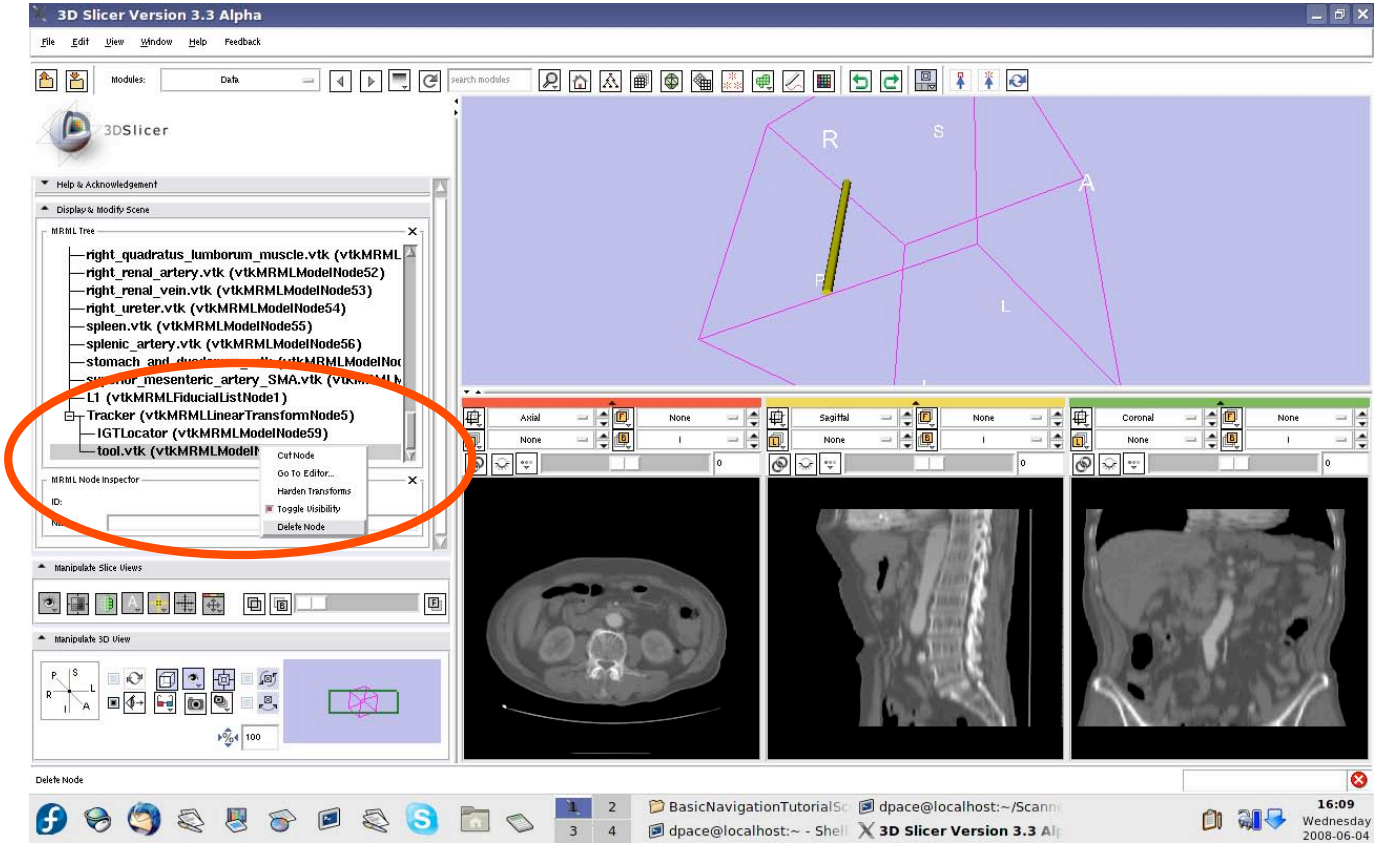
Reslice the images using the tracker transform

Delete the Calibration Matrix by right-clicking and selecting “Delete Node”



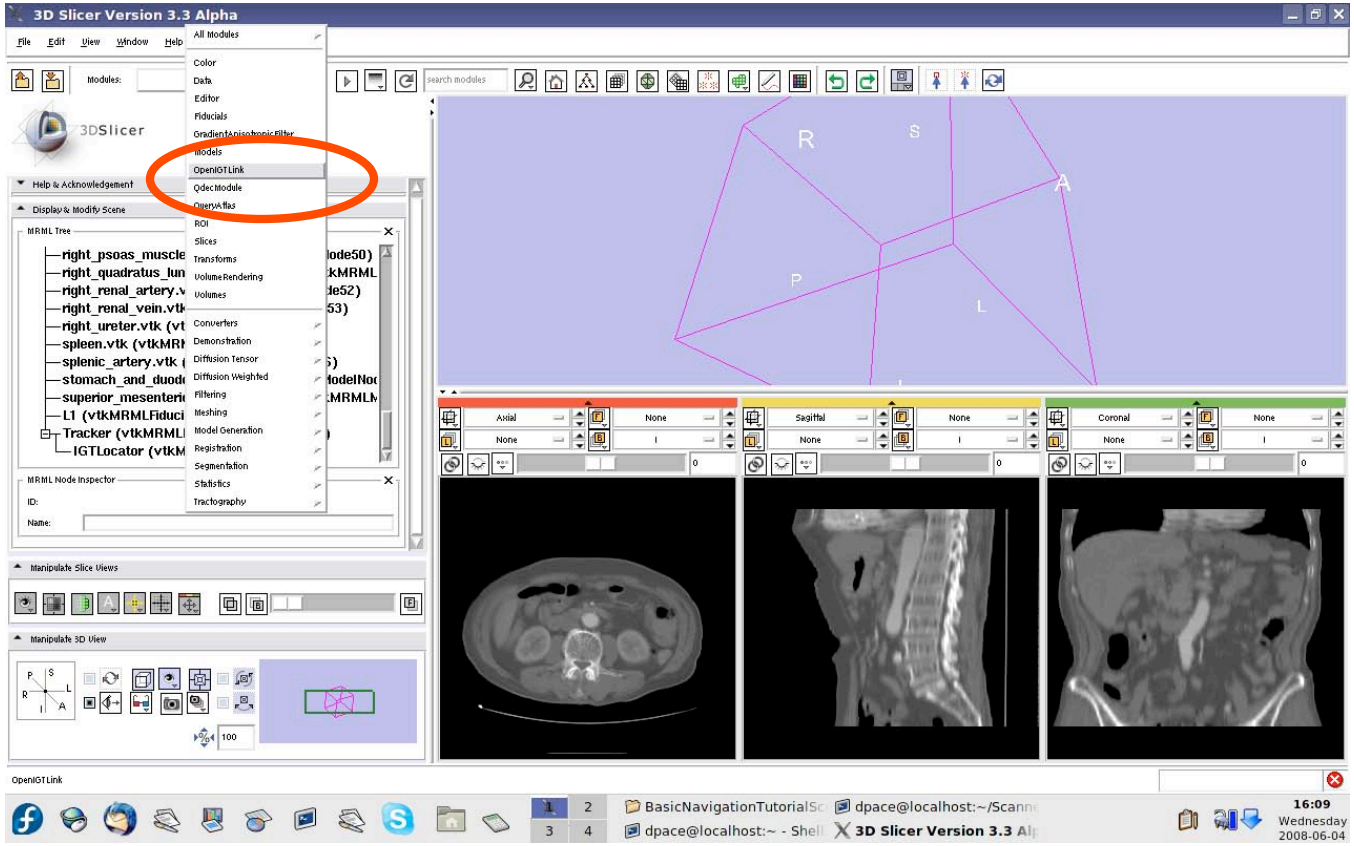
Reslice the images using the tracker transform

Delete the tool model by right-clicking on tool.vtk and selecting "Delete Node"



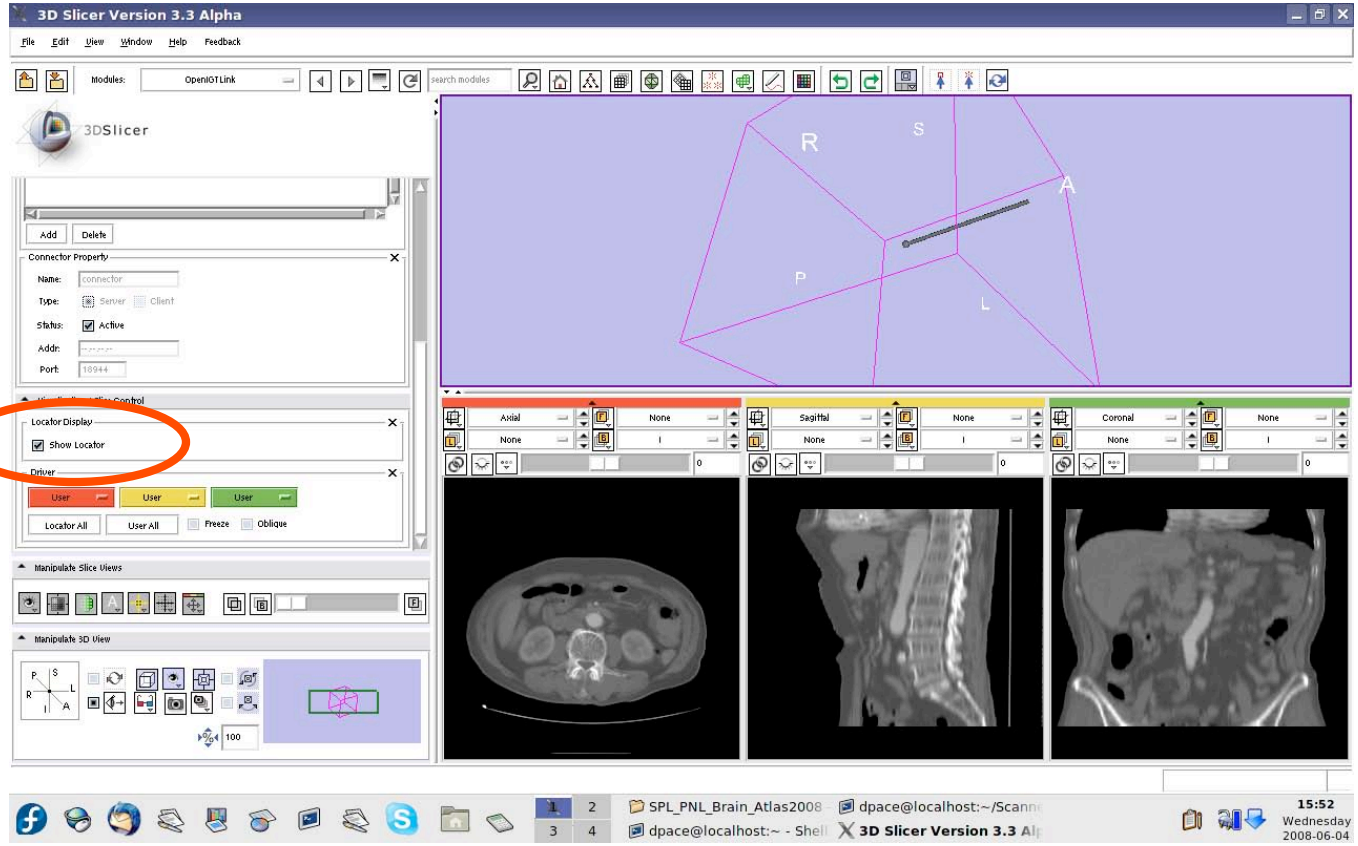
Reslice the images using the tracker transform

Open the OpenIGTLink module



Reslice the images using the tracker transform

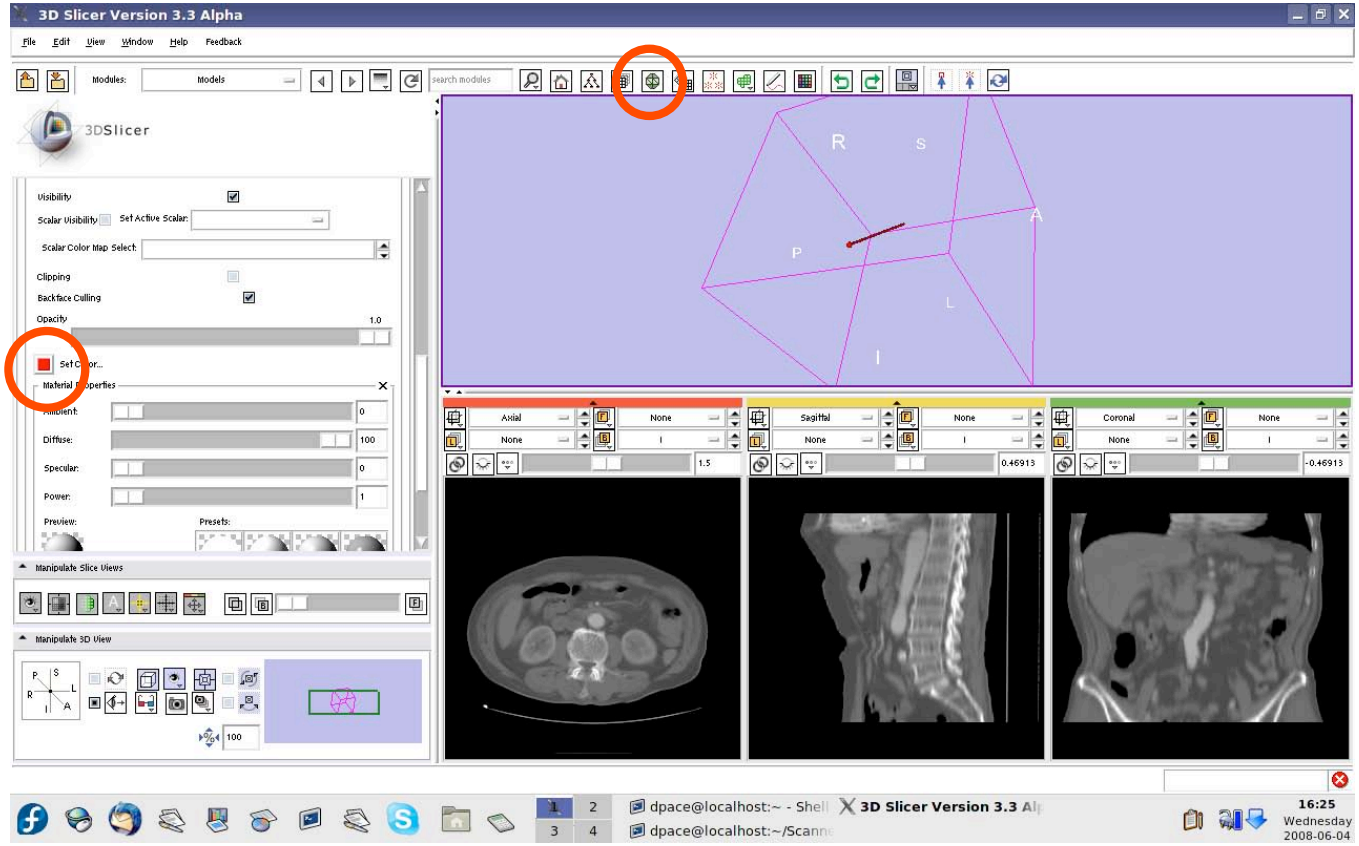
In the Visualization/ Slice Control pane, click the “Show Locator” button



Reslice the images using the tracker transform

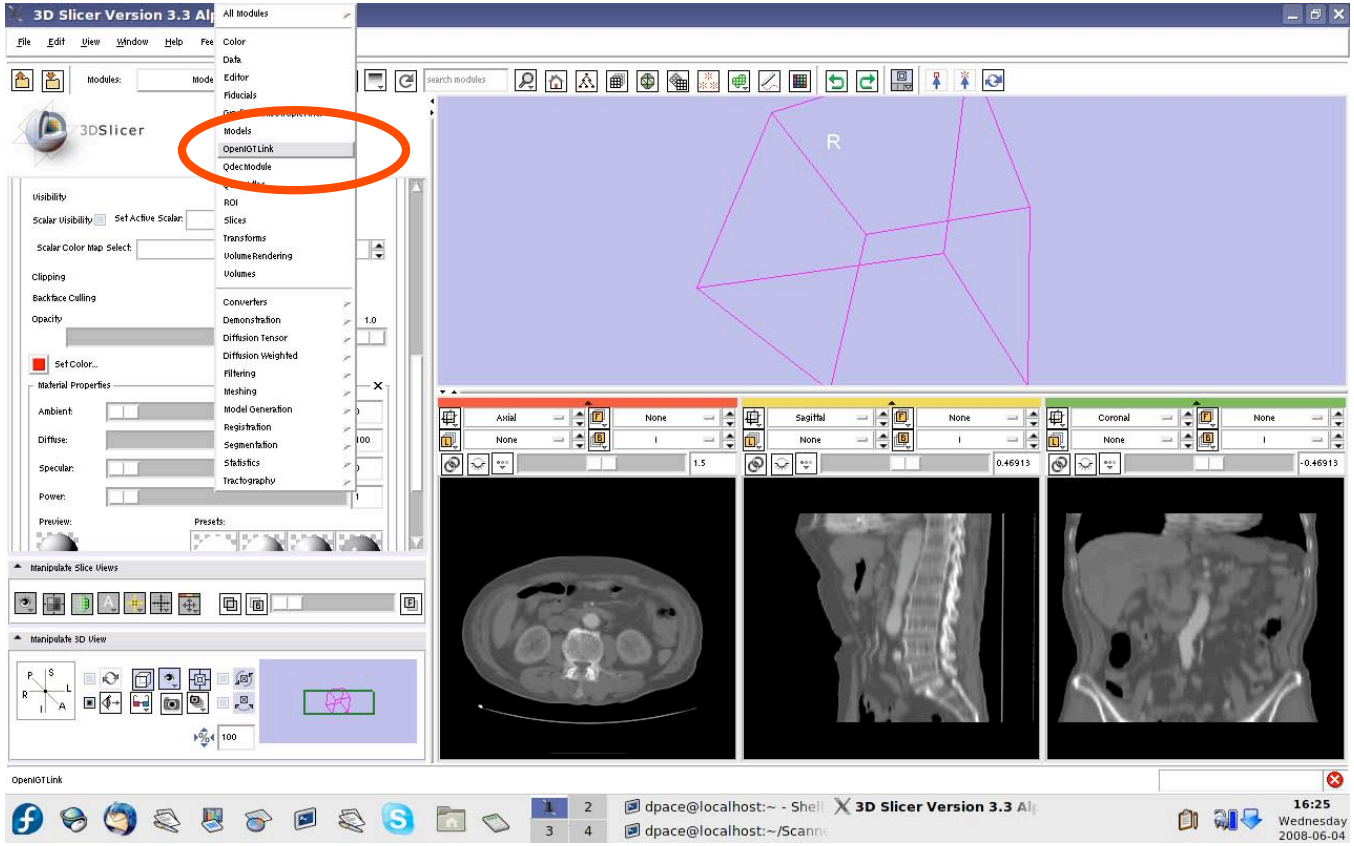
Open the Models module

Select the IGTLocator model as the selected model and change its colour to red



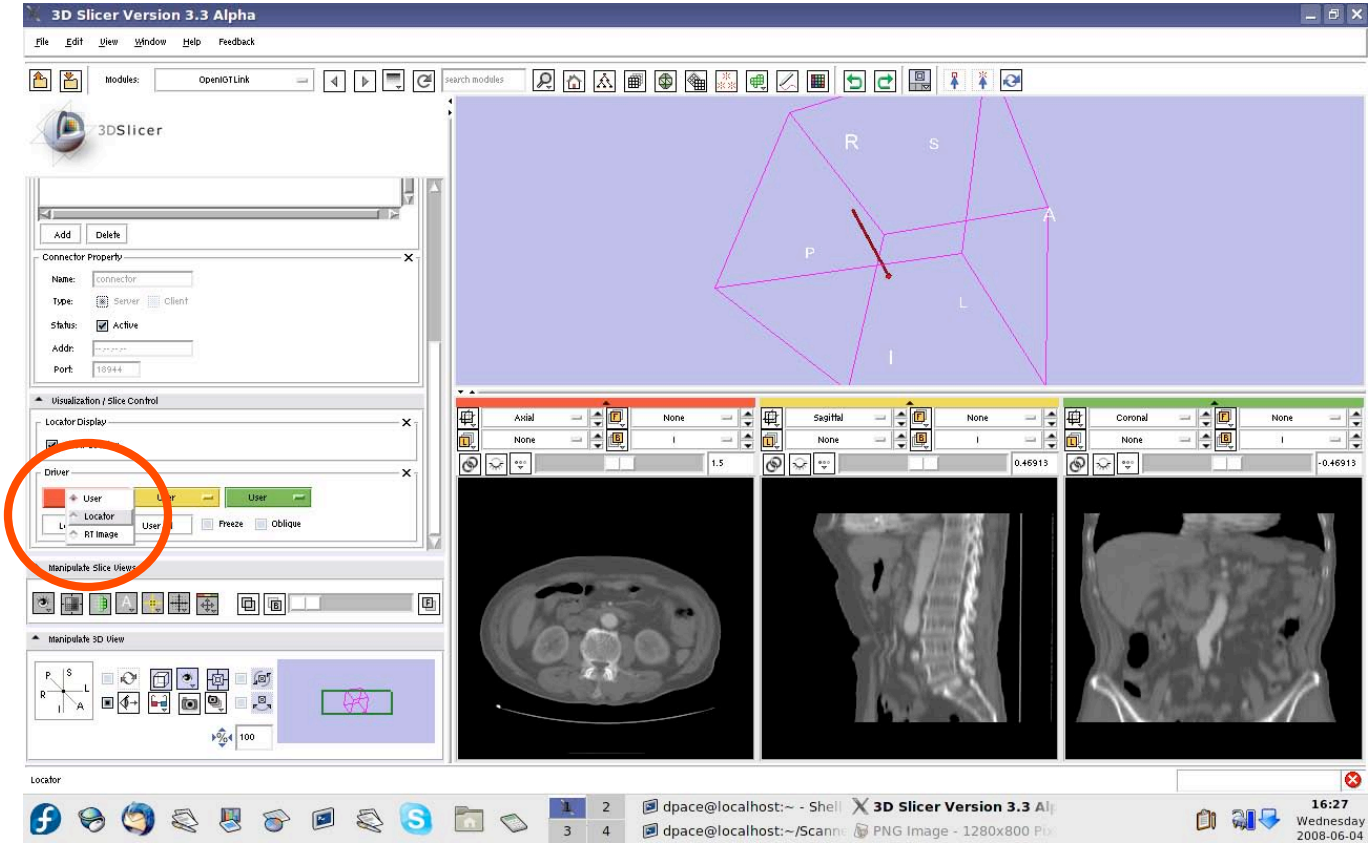
Reslice the images using the tracker transform

Open the OpenIGTLink module



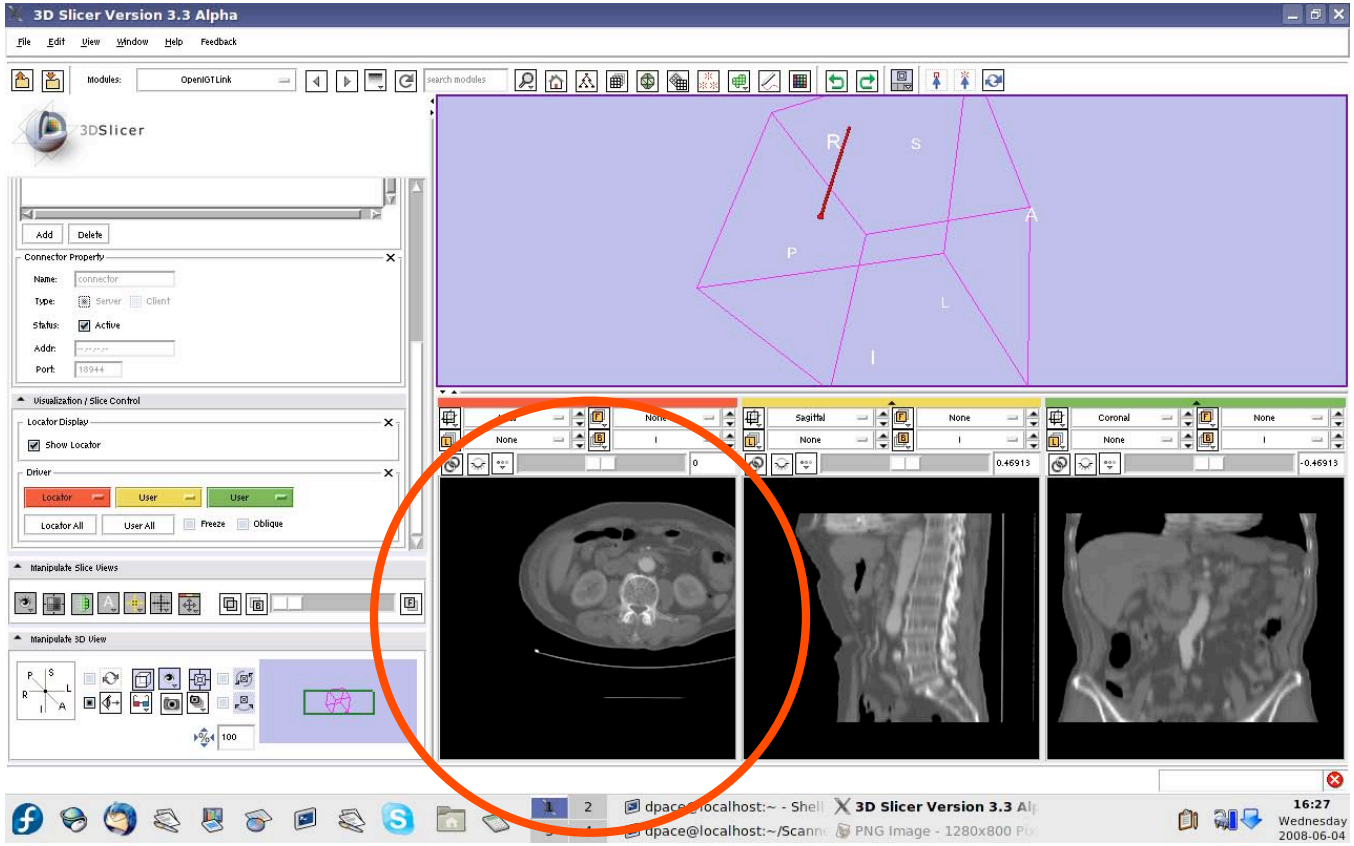
Reslice the images using the tracker transform

Set the driver for the red (axial) slice to “Locator”



Reslice the images using the tracker transform

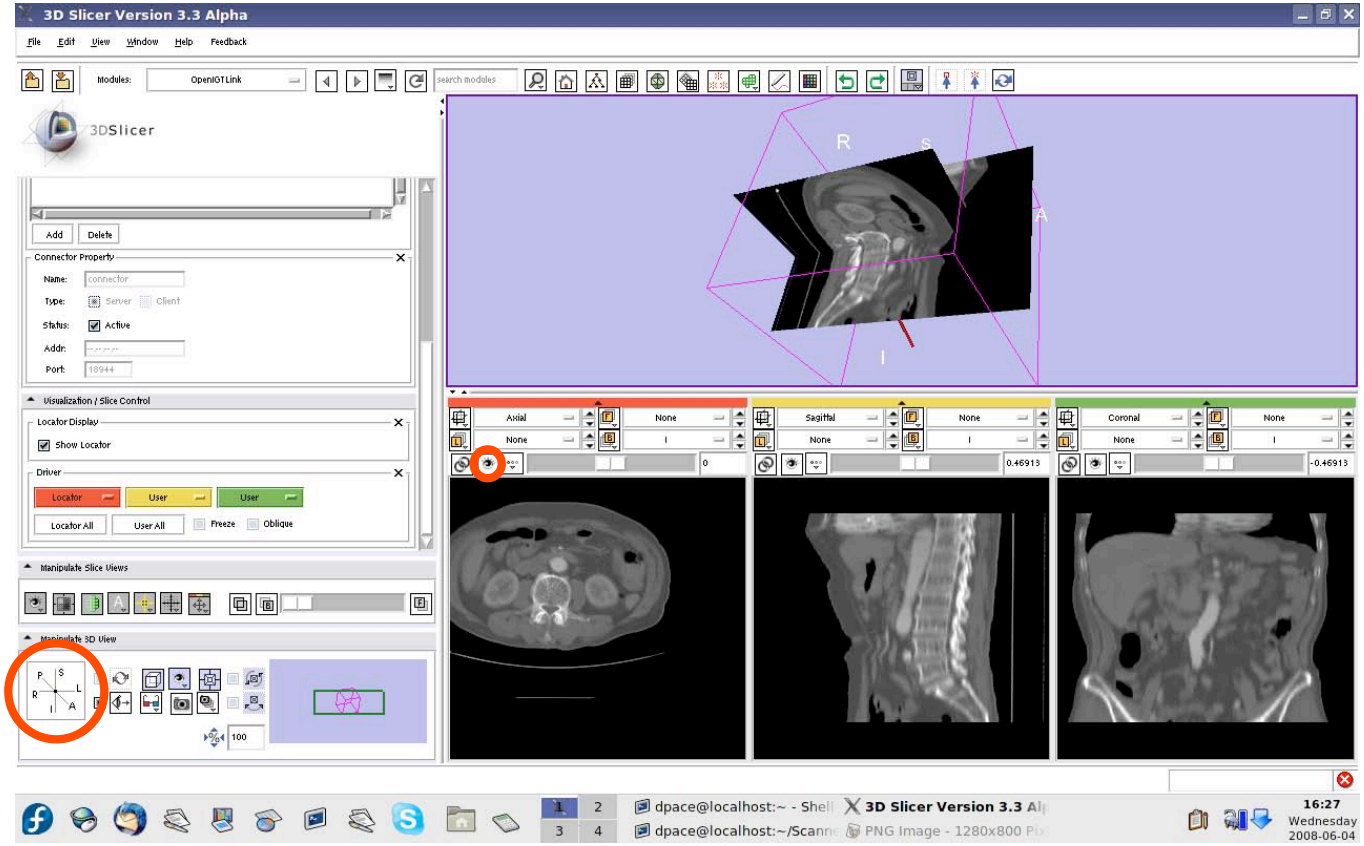
The axial slice moves as the locator moves



Reslice the images using the tracker transform

Click on the “visibility” button

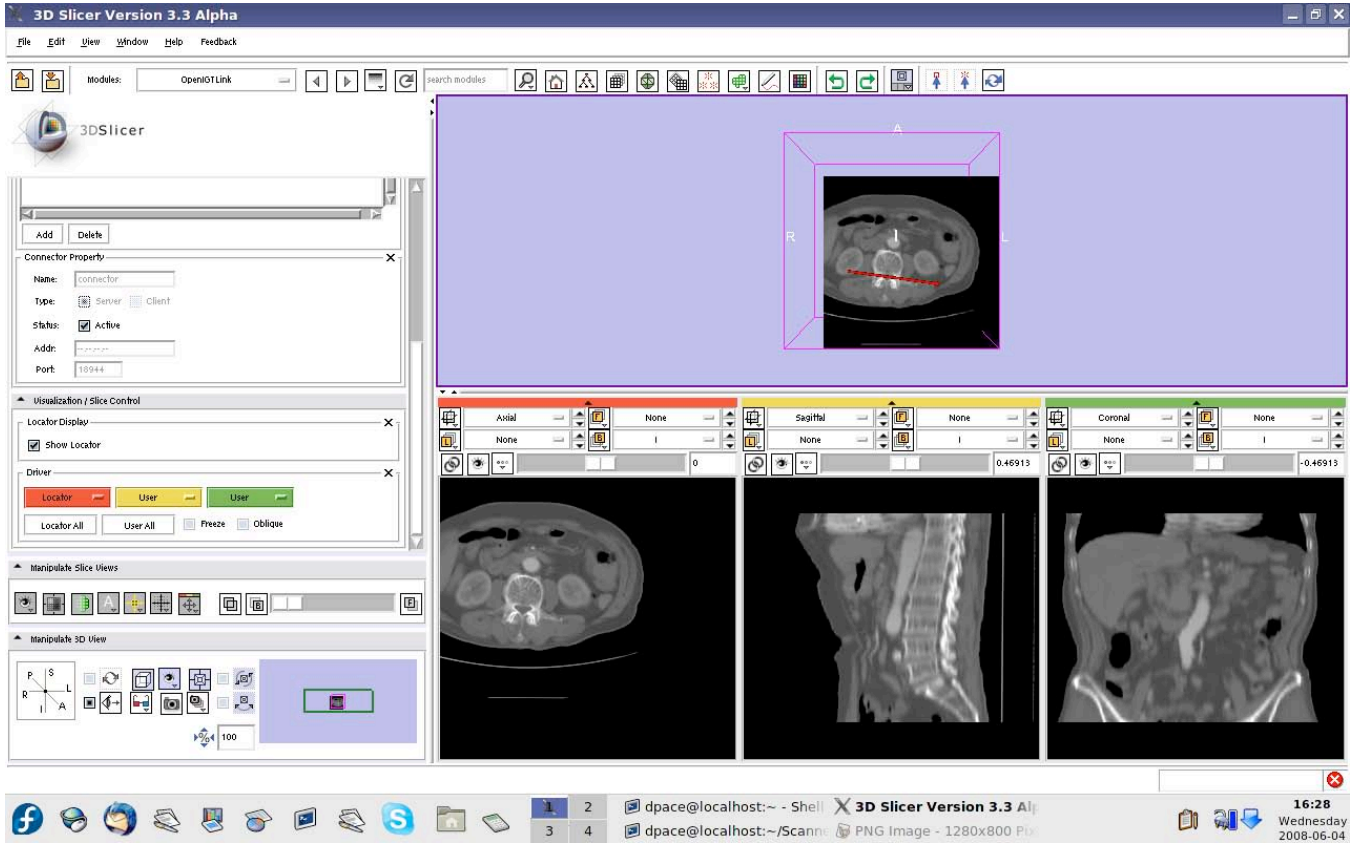
Change the view in the 3D viewer by clicking on the “I” (inferior) button on the “Manipulate 3D View” pane



Reslice the images using the tracker transform

Note that the axial slice moves as the locator moves

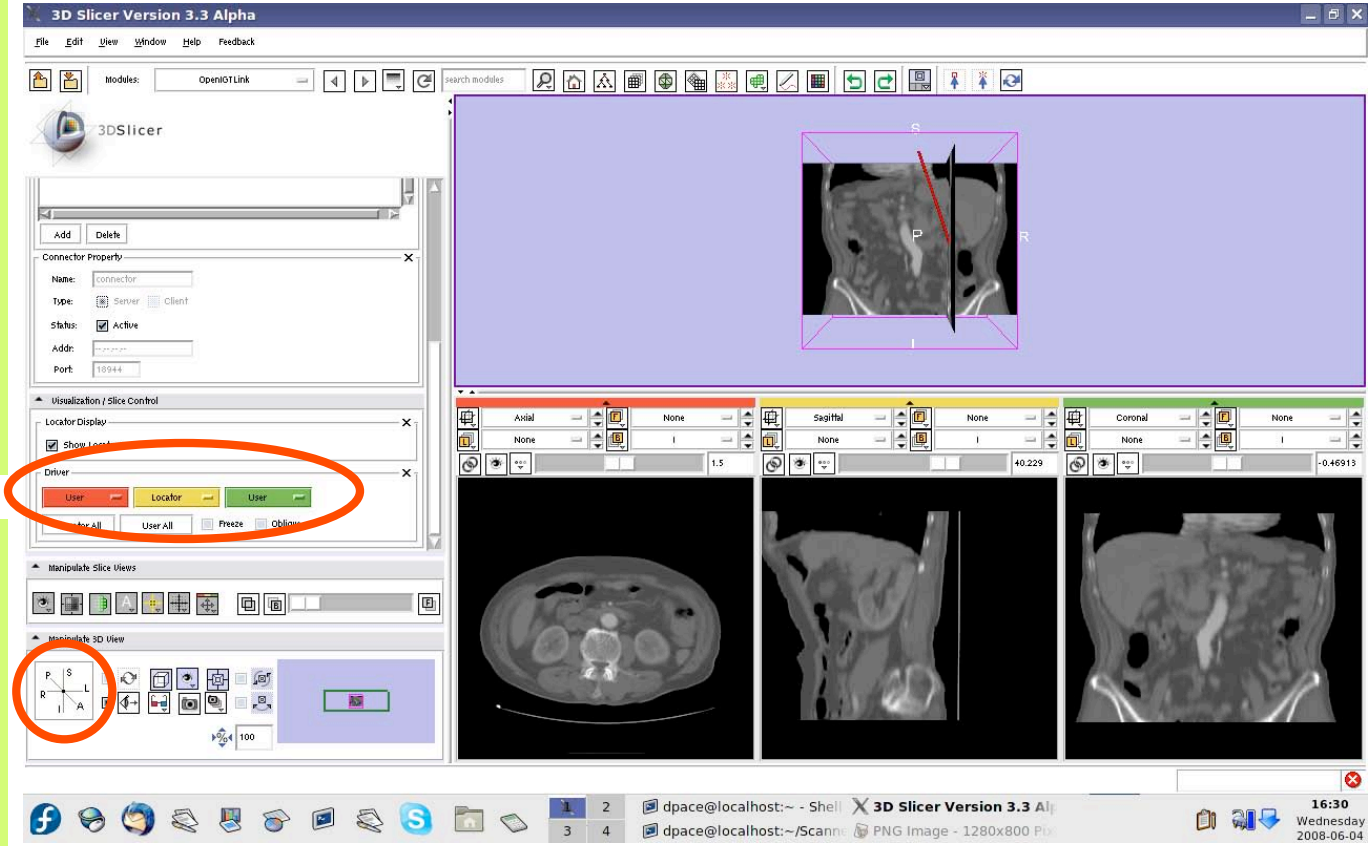
This is because the image origin in the left-right direction is set to the locator's position in the left-right direction



Reslice the images using the tracker transform

Set the driver for the red (axial) slice to “User” and the driver for the yellow (sagittal slice) to “Locator”

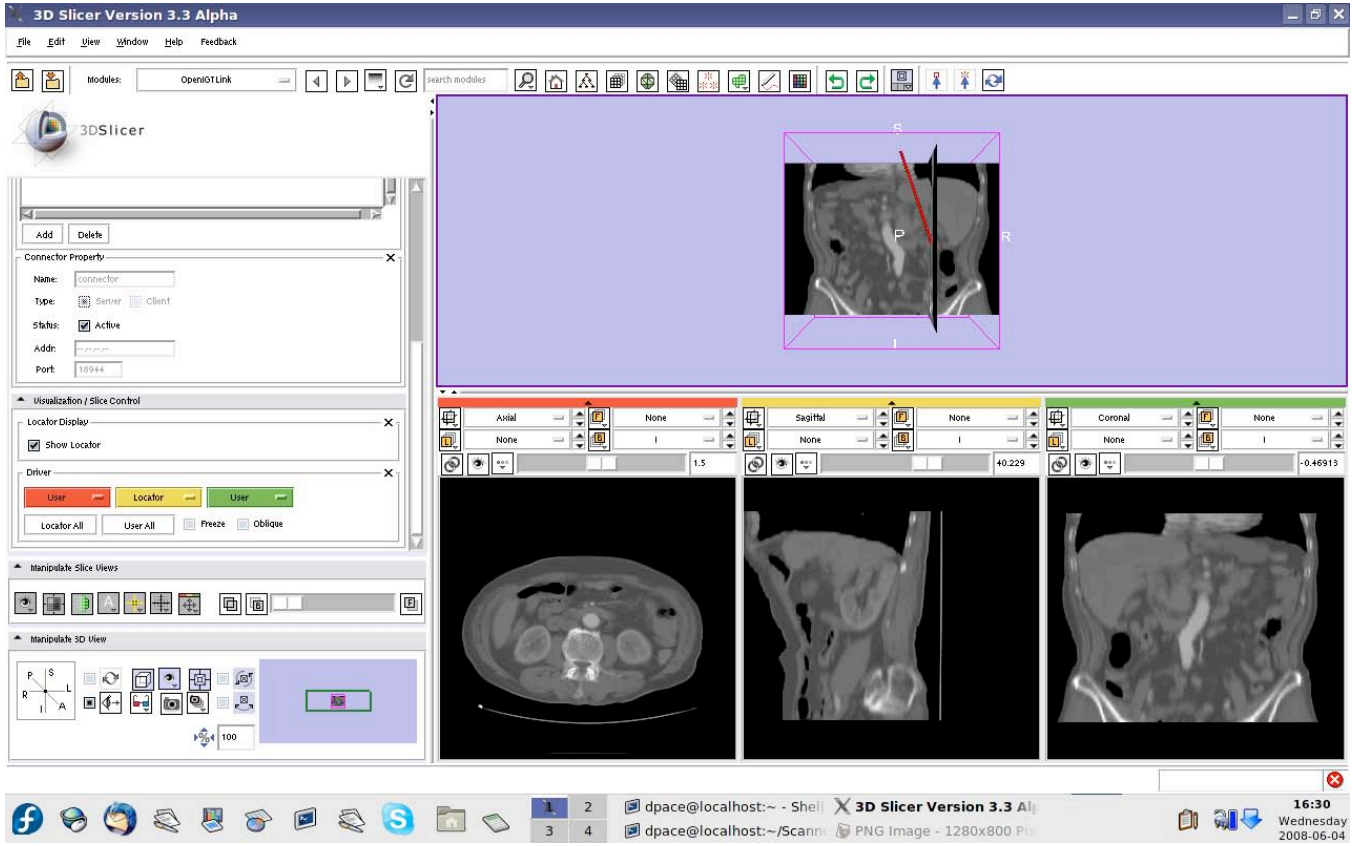
Click on the “P” (posterior) button on the “Manipulate 3D View” pane



Reslice the images using the tracker transform

Note that the sagittal slice moves from left to right as the locator moves

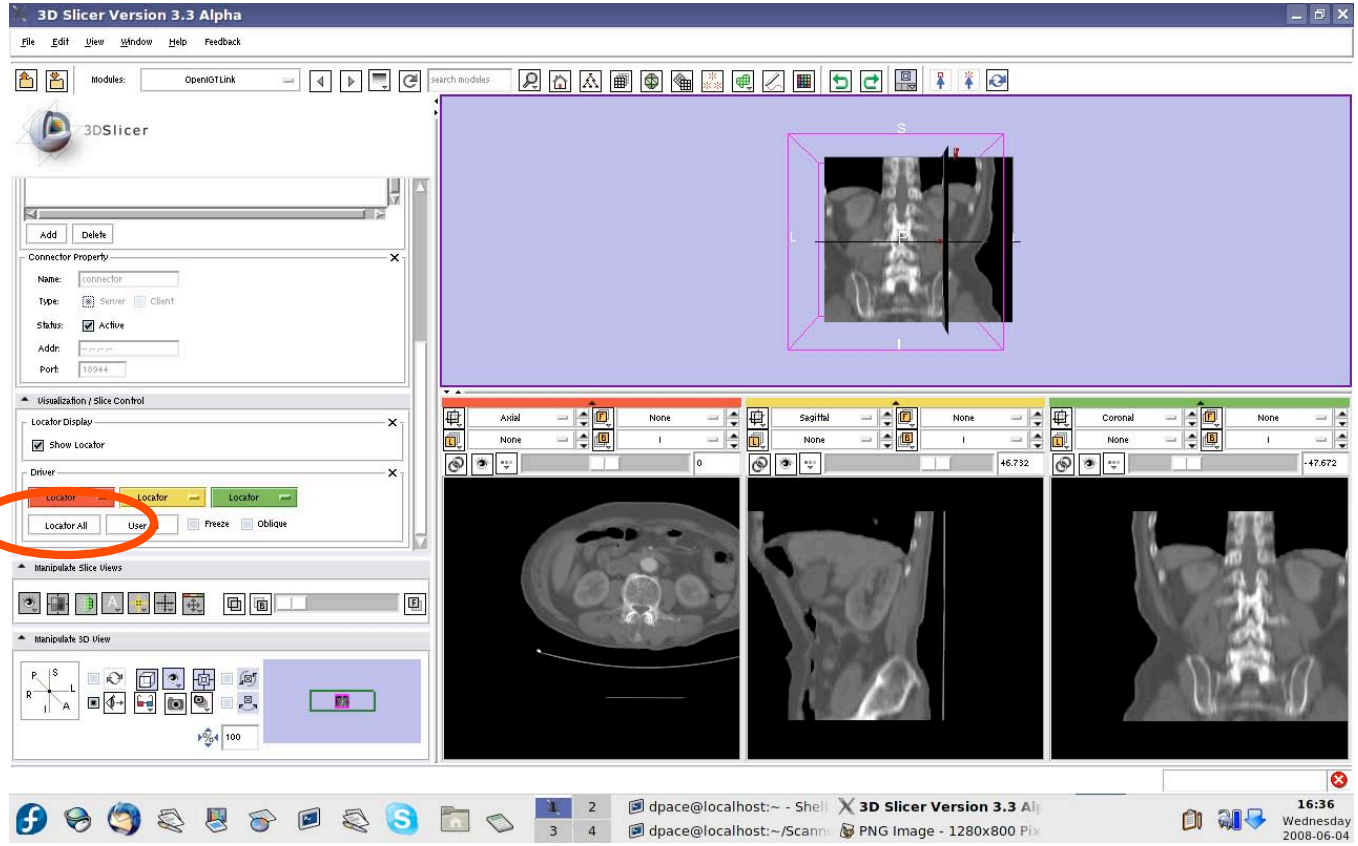
(The axial slice didn't move up and down because the locator does not move in the superior-inferior direction)



Reslice the images using the tracker transform

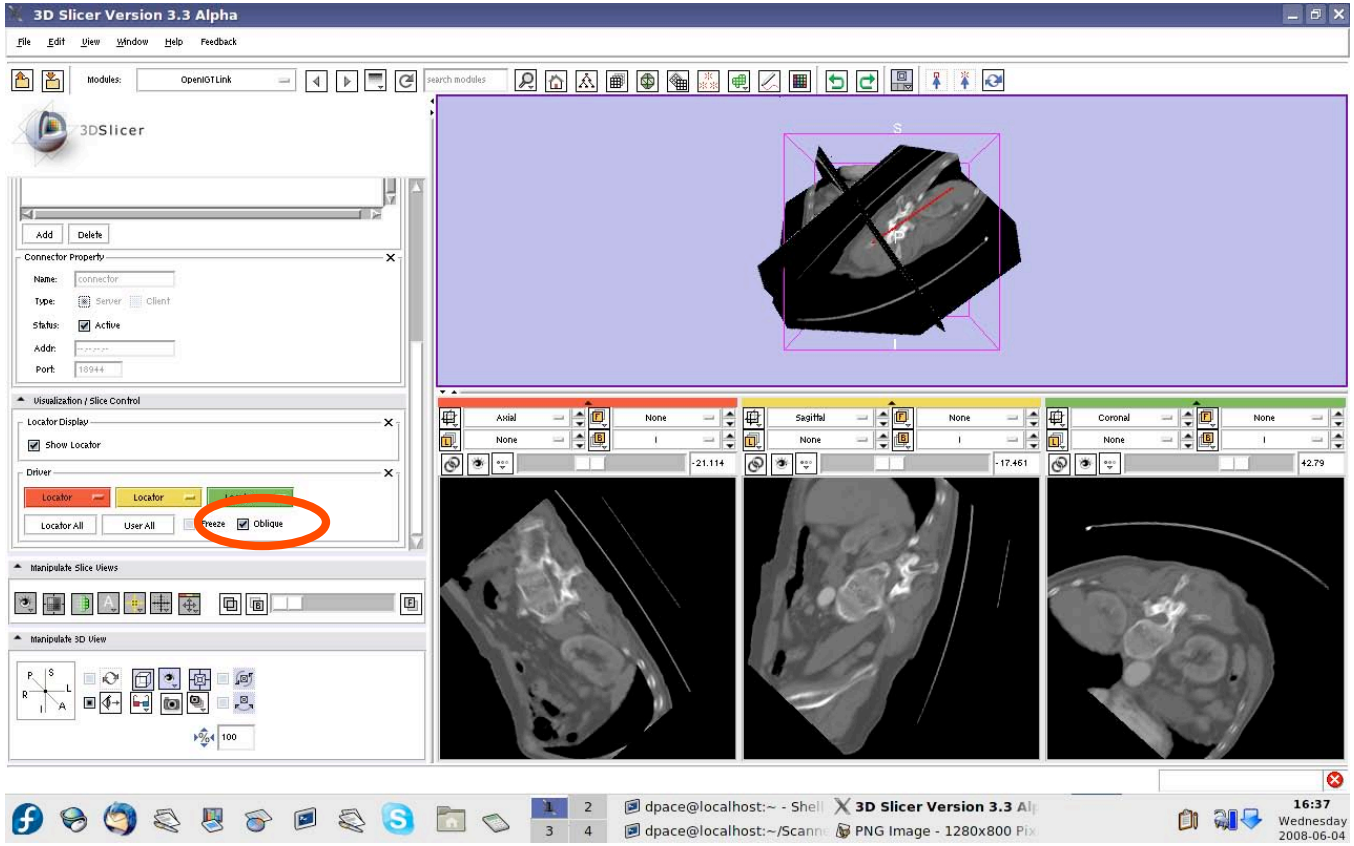
You can click on the "Locator All" button to set the driver to "Locator" for all of the slice views.

The image origin is set to the locator's position.



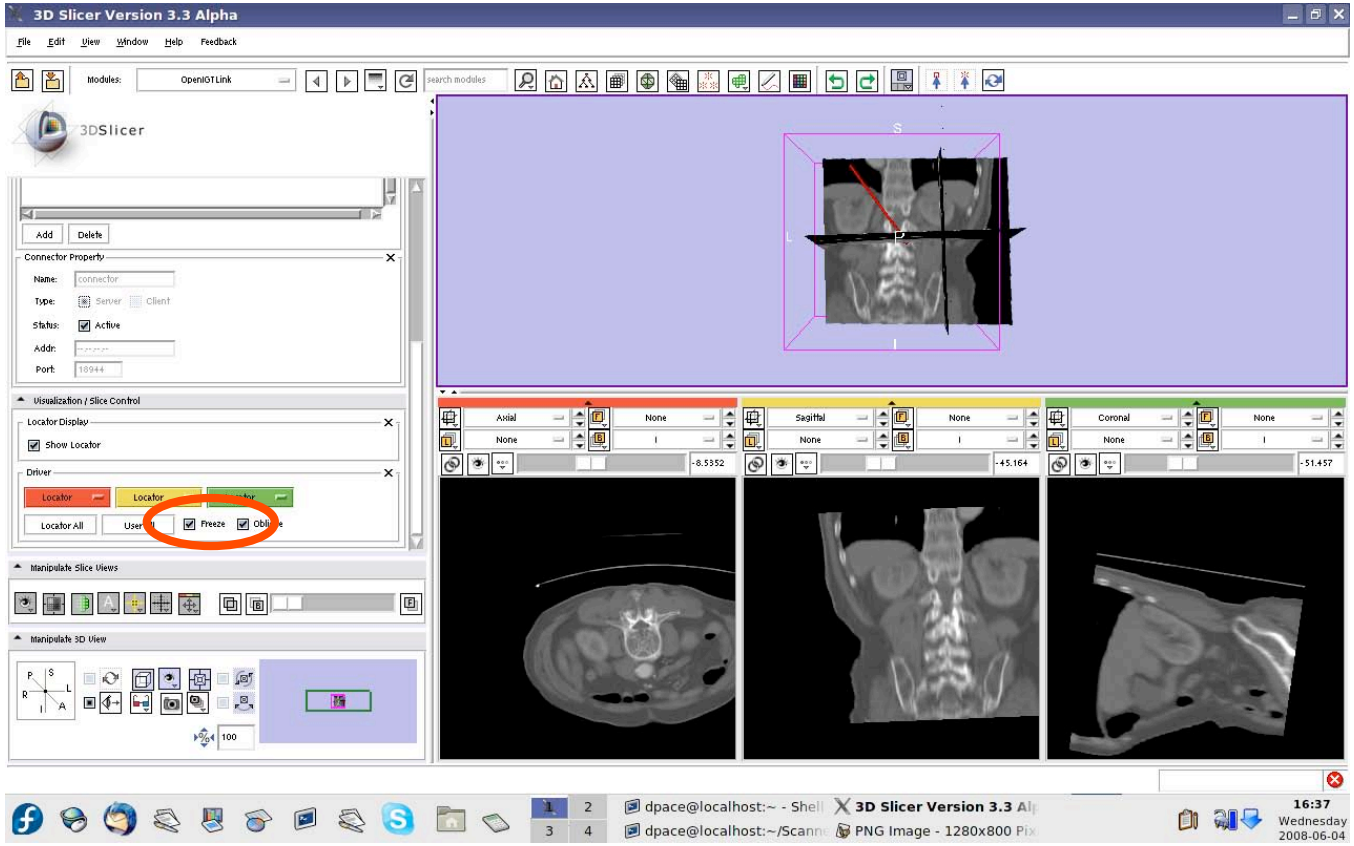
Reslice the images using the tracker transform

Check the “oblique” box to slice the image volume according to the tool’s orientation - the coordinate system is setup so that one axis is parallel to the locator’s orientation



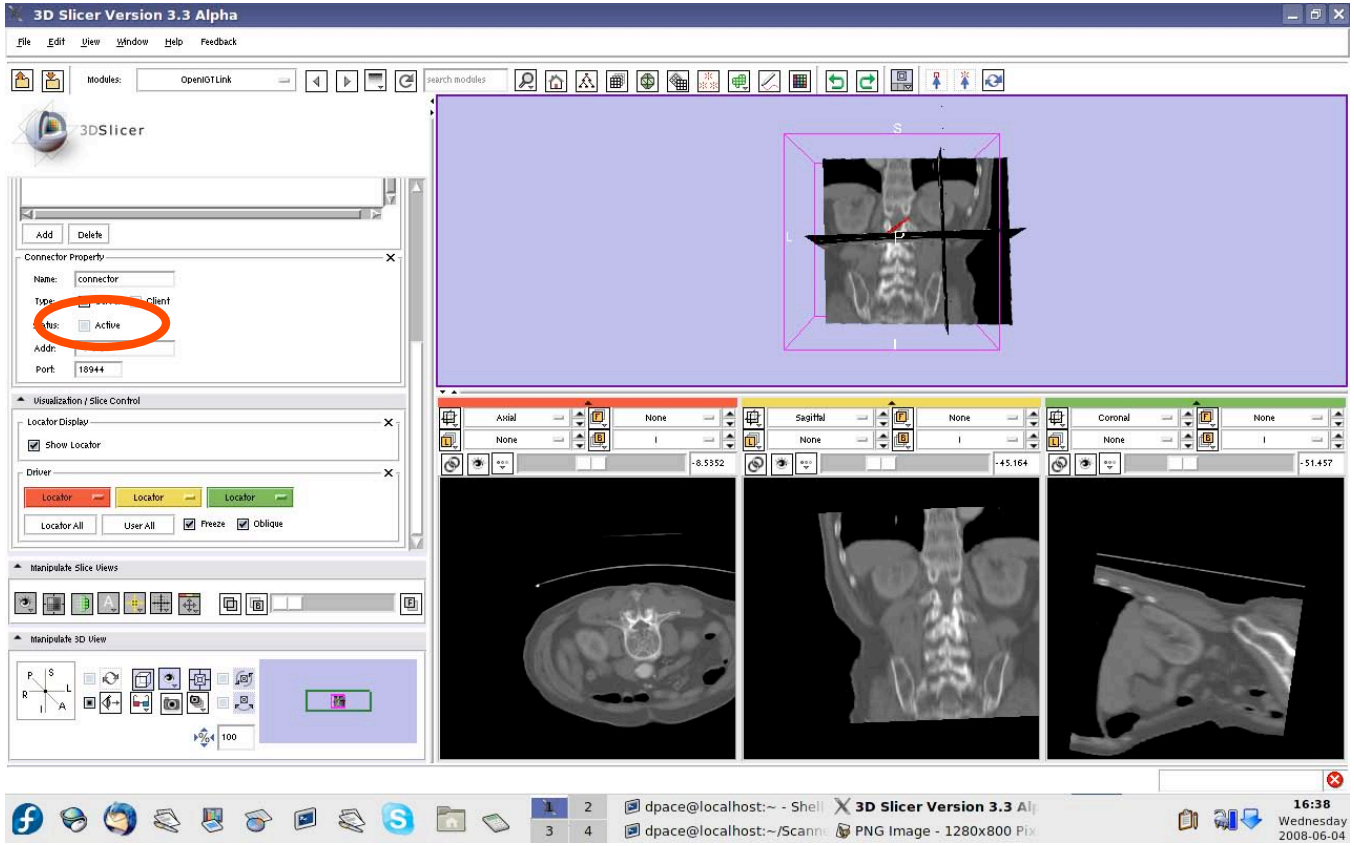
Reslice the images using the tracker transform

Check the "Freeze" box to freeze the images in both the 3D Viewer and the three slices viewers (the locator keeps moving)



Turn off the OpenIGTLink connection

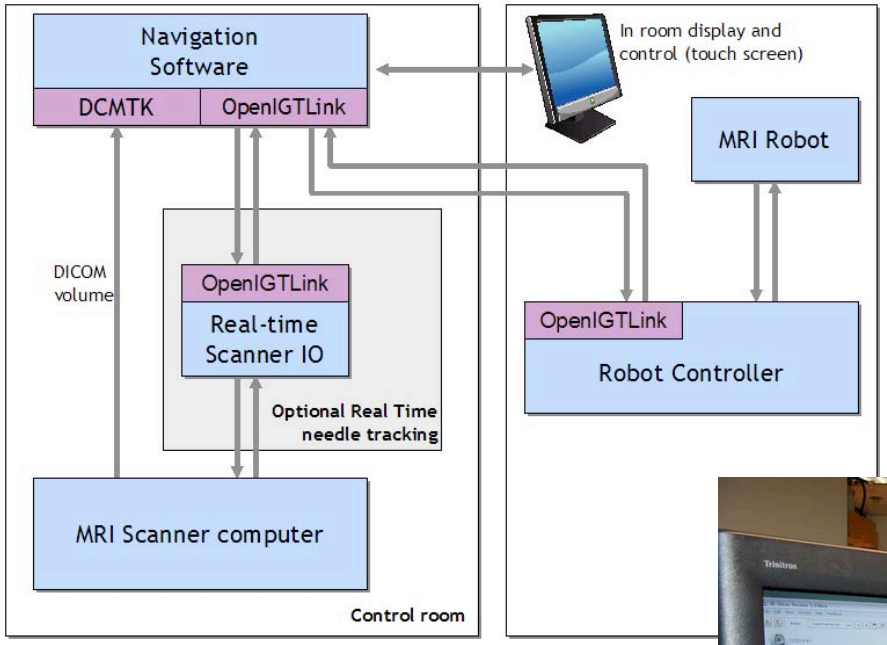
Click on the “Active” box to disconnect the OpenIGTLink connection



Tutorial outline

1. Introduction to surgical navigation
2. Interfacing Slicer3 with external devices using OpenIGTLink
3. Hands-on navigation using a tracking simulator
4. **Examples of OpenIGTLink in use**

Examples of OpenIGTLink in use



Prostate biopsy robot under MRI-guidance

Volume-rendered 4D ultrasound

Overview

- In this tutorial, you learned:
  - How OpenIGTLink can be used to perform navigation in Slicer3
  - How to set up OpenIGTLink connections using the OpenIGTLink module in Slicer3
  - How to visualize the tracker transforms
  - How to reslice image volumes using the tracker transforms
  - How OpenIGTLink is currently being used in practice

Conclusions

- Slicer3 can interact with common devices used in Image Guided Therapy
- OpenIGTLink is evolving technology - expect lots of active development!
- Slicer3 is free open-source software that allows IGT researchers to share algorithms and work within a common framework

For more information…

- The Slicer3 IGT Advanced Navigation Tutorial uses the Aurora magnetic tracking devices from NDI, and provides a more thorough explanation of the OpenIGTLink protocol:

  http://wiki.na-mic.org/Wiki/index.php/IGT:ToolKit/Navigation-with-Aurora

- For a description of the OpenIGTLink protocol: http://www.na-mic.org/Wiki/index.php/OpenIGTLink