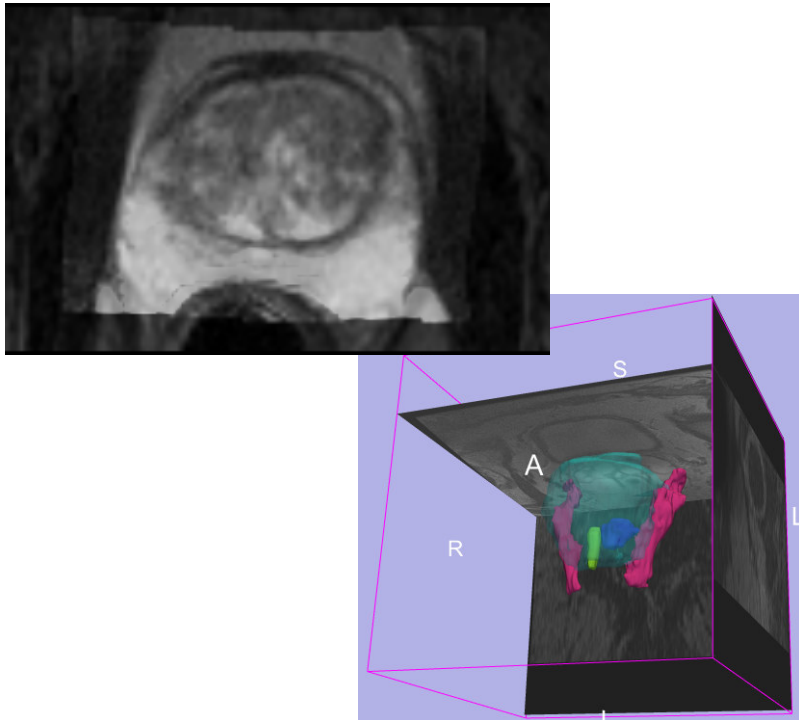




Slicer3 Training Compendium

MR-guided prostate interventions using the NA-MIC Kit



Danielle Pace, B.CmpH
and Sota Oguro, M.D.

Surgical Planning Laboratory

Brigham and Women's Hospital

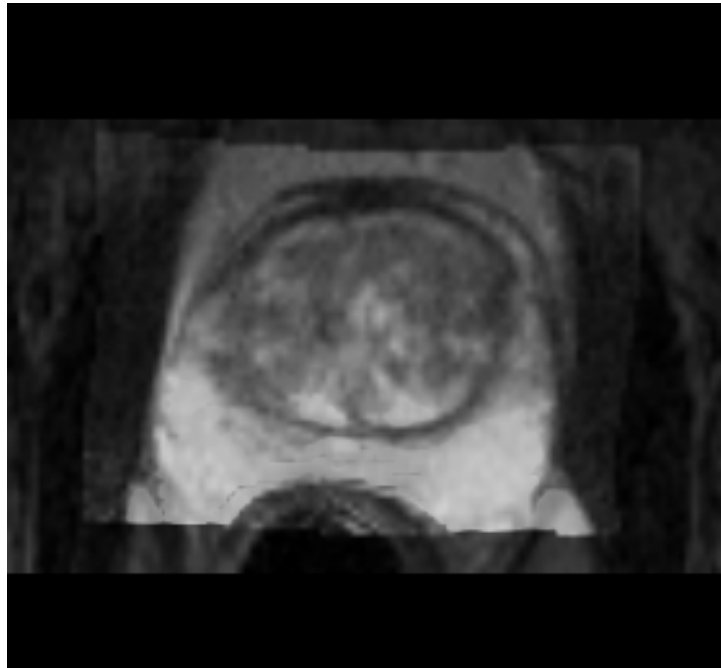
Harvard Medical School

Massachusetts General Hospital



Learning Objective

This tutorial will teach you how to perform the steps required for MR-guided prostate interventions using Slicer3.



In particular, you will learn how to:

- Register pre-operative and intra-operative prostate MR images using deformable B-spline registration
- Incorporate models of the neurovascular bundle using image segmentation and model making



Prerequisites

This tutorial assumes that you have already completed the tutorial **Data Loading and Visualization**. Tutorials for **Slicer3** are available at the following location:

- **Slicer3** tutorials

<http://www.na-mic.org/Wiki/index.php/Slicer3.2:Training>

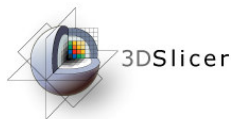


Materials

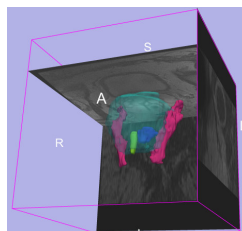
This tutorial requires the installation of the **Slicer3** software and the tutorial dataset. They are available at the following locations:

- **Slicer3** download page (***Slicer 3.2***)
<http://www.slicer.org/pages/Downloads/>
- Tutorial dataset (***MRGuidedProstateInterventions.zip***)
<http://wiki.na-mic.org/Wiki/index.php/IGT:ToolKit/Prostate-Planning>

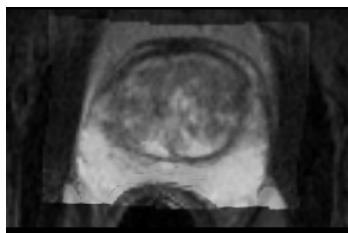
Disclaimer: *It is the responsibility of the user of Slicer to comply with both the terms of the license and with the applicable laws, regulations, and rules.*



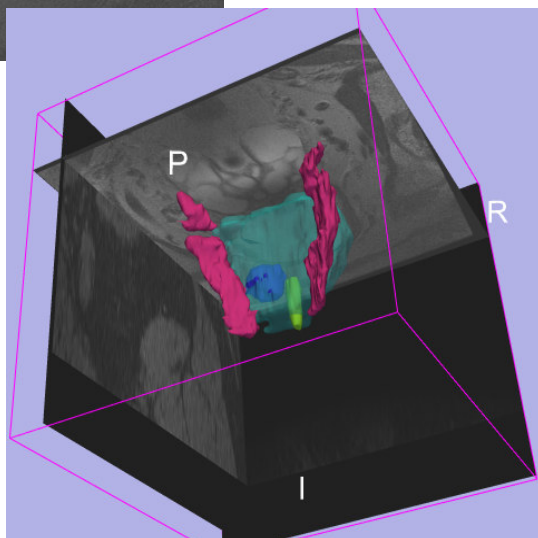
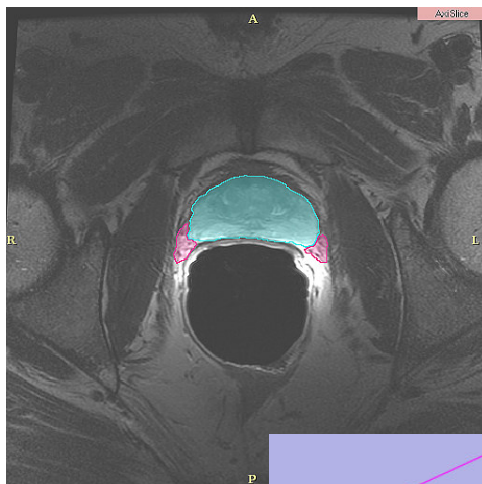
Overview



1. MR-guided prostate interventions: clinical background



2. Registering pre-operative & intra-operative prostate MR images using deformable B-spline registration

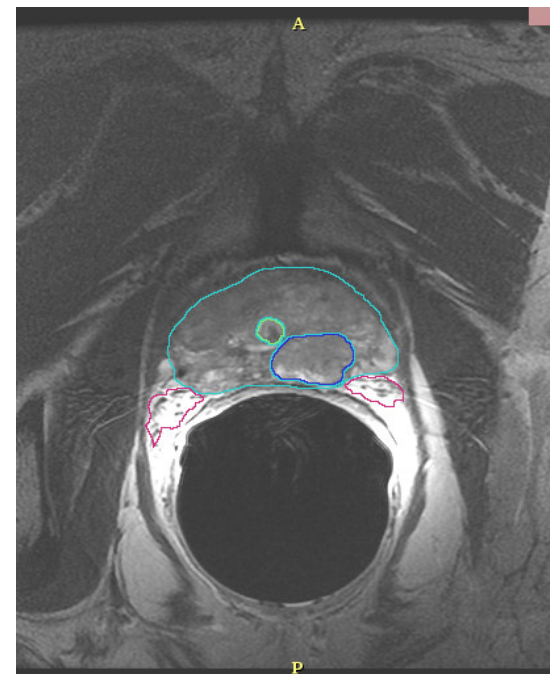


MR-guided prostate interventions: clinical background



Prostate cancer

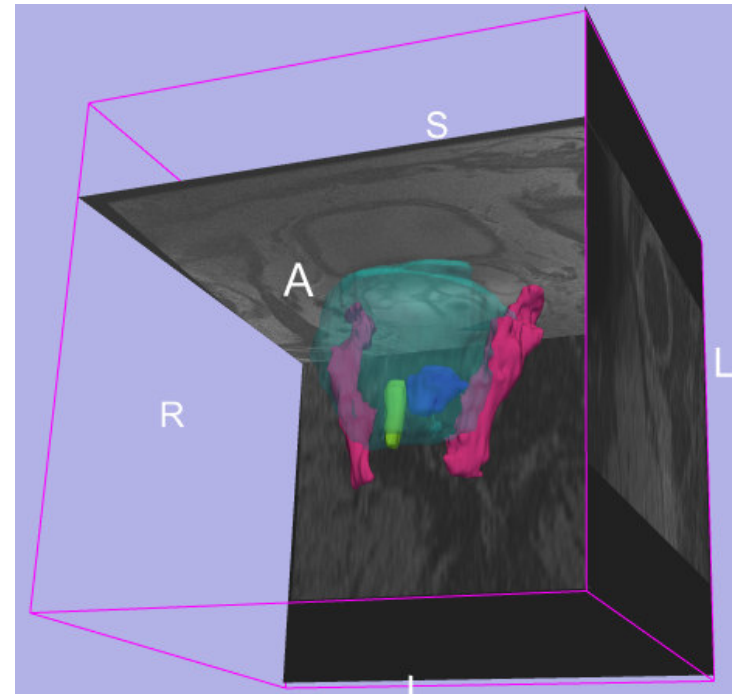
- Prostate cancer has the second-highest mortality rate of all cancers in American men: one in six men will be diagnosed, and it kills one in thirty-five (American Cancer Society)
- **Diagnosis:**
 - Prostate specific antigen (PSA) level
 - Digital rectal exam
 - **Needle biopsy** (Gleason score)
- **(Some) Treatment options:**
 - “Watchful waiting”
 - **Brachytherapy**
 - External beam radiation therapy
 - Radical prostatectomy





Guidance for biopsy/brachytherapy

- ***Image guidance:***
 - allows specific locations within the prostate to be targeted
 - provides updates of the needle's current position and orientation
- Models can be used to highlight the prostate, the tumour, and structures to be avoided (such as the neurovascular bundle)





MR-guided prostate interventions

pre-operative

pre-operative
MR imaging
(high quality)

(optional)
segmentation
model making

registration



- compensates for
- change in patient position
 - presence/absence of endorectal coil

intra-operative

intra-operative
MR imaging
(lower quality)

**Guidance based on
intra-operative
image fused with
higher quality pre-
operative image and
models of important
structures**



The Prostate MR Image Database

<http://prostatemrimage.com>

- Provides prostate MR images for a variety of clinical situations, including prostate cancer biopsy and brachytherapy

Prostate MR Image Database

Welcome!

Getting Started

- Get right to it... view the [image database](#)
- Browse clinically relevant [image data](#) related to the cases in the database.
- [Scope and Purpose](#) of this database.
- Frequently asked [questions](#).
- [What's new](#) in the database.
- [Glossary](#) of terms used.

For Clinicians

- [Background](#) and introduction to prostate MR imaging.
- Overview of the ongoing [Image Guided Therapy Program](#) at Brigham and Women's Hospital, including multi-media presentations.
- A selection of [interesting cases](#) from the database.
- A [bibliography](#) for prostate MRI imaging and image-guided therapy.


For Scientists and Engineers

- Technical details on the [image formats](#) used here.
- [Code](#) for reading the images and header information.
- [Slicer](#), the recommended platform for viewing and processing image volumes.
- [Other Code](#) for processing images, such as registration code.

Other Relevant Links


- A [database of publications](#) from our group.
- [Affiliated laboratories](#) and external collaborators.
- [External links](#) related to prostate disease, imaging and therapy.

Privacy Statement and Acknowledgements



Prostate MR Image Database

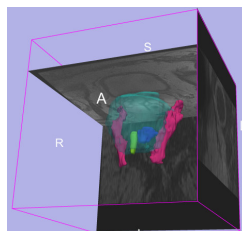
Patient/Exam List



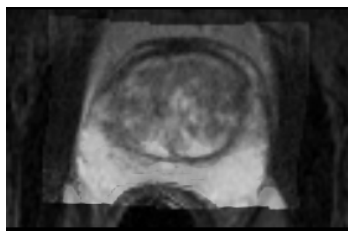
Patient	Exam	Exam Description	Number Of Series	Exam Date	View	Download
000001	00001	PROSTATE BIOPSY	2	Day 42	View	Download
000001	00002	PROSTATE	5	Day 1	View	Download
000002	00001	BRACHYTHERAPY	1	Day 59	View	Download
000002	00002	PROSTATE	5	Day 1	View	Download
000003	00001	BRACHYTHERAPY	1	Day 255	View	Download
000003	00002	PROSTATE STAGING	5	Day 1	View	Download
000004	00001	PROSTATE BX	2	Day 96	View	Download
000004	00002	PROSTATE	9	Day 1	View	Download
000005	00001	BRACHYTHERAPY	2	Day 114	View	Download
000005	00002	PROSTATE	5	Day 1	View	Download
000006	00001	BRACHYTHERAPY	1	Day 148	View	Download
000006	00002	PROSTATE	5	Day 1	View	Download
000007	00001	PROSTATE BX	2	Day 1	View	Download
000008	00001	BRACHYTHERAPY	1	Day 99	View	Download
000008	00002	PROSTATE	5	Day 1	View	Download
000009	00001	BRACHYTHERAPY	1	Day 72	View	Download
000009	00002	PROSTATE W/ SPEC	4	Day 1	View	Download
000010	00001	BRACHYTHERAPY	2	Day 77	View	Download



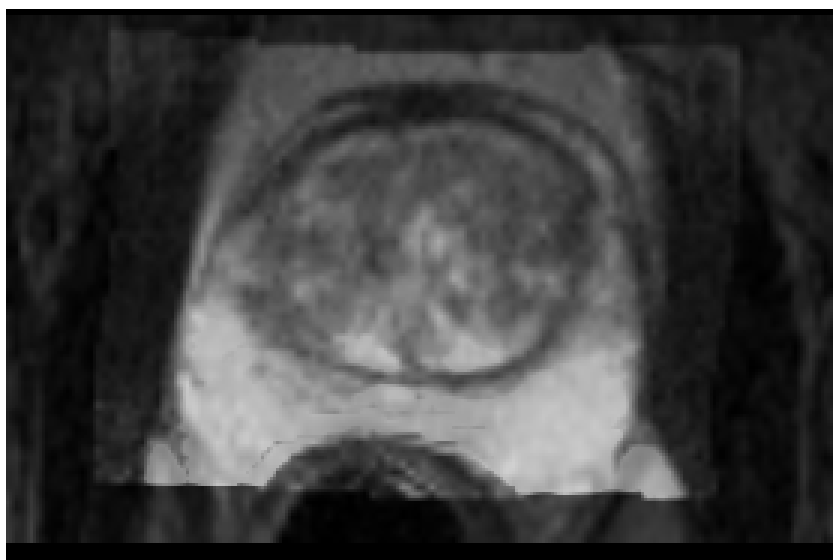
Overview



1. MR-guided prostate interventions: clinical background



2. Registering pre-operative & intra-operative prostate MR images using deformable B-spline registration



Registering pre-operative & intra-operative prostate MR images

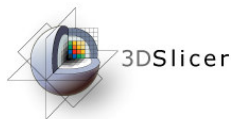
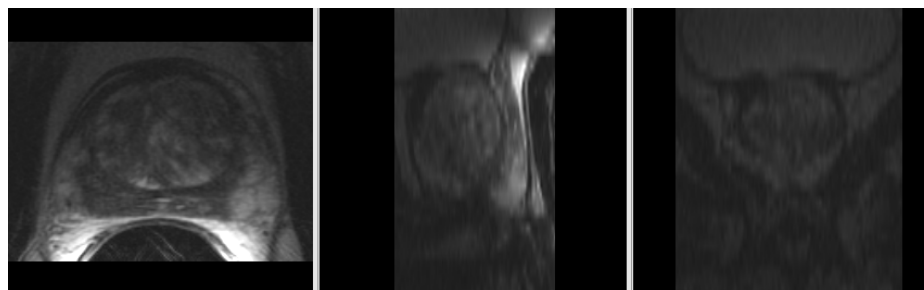


Image Registration

- Image registration aligns two images together with the goal of making the corresponding anatomy overlap

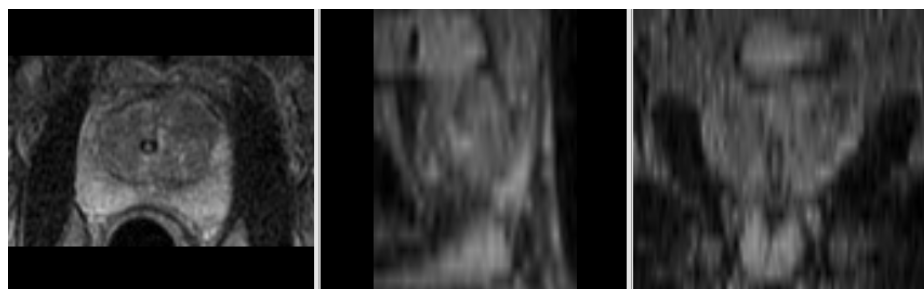
Pre-operative

- T2 FSE at 1.5 T, endorectal coil
- pixel spacing:
0.46875mm x 0.46875mm
- slice thickness: 3mm



Intra-operative

- T2 FSE at 0.5 T, body coil
- pixel spacing:
0.9375mm x 0.9375mm
- slice thickness: 5mm



Three transformation models

Rigid



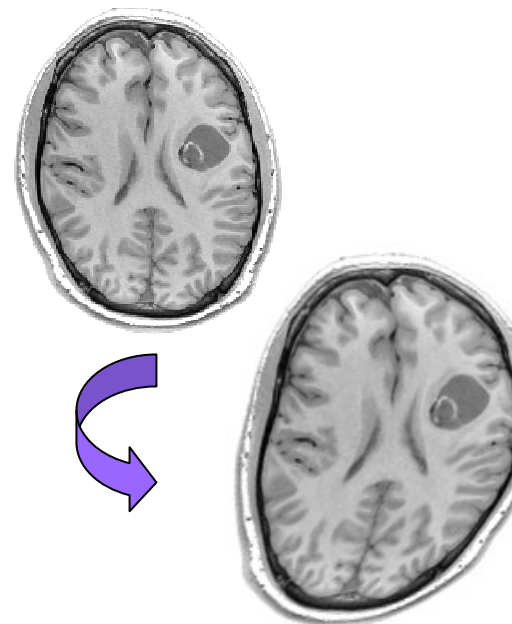
- Translation
- Rotation

Affine



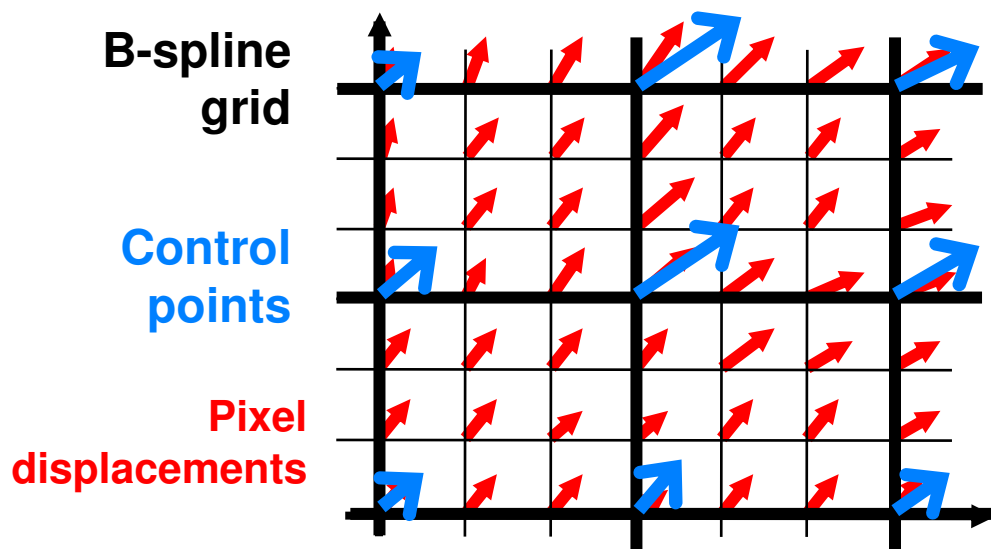
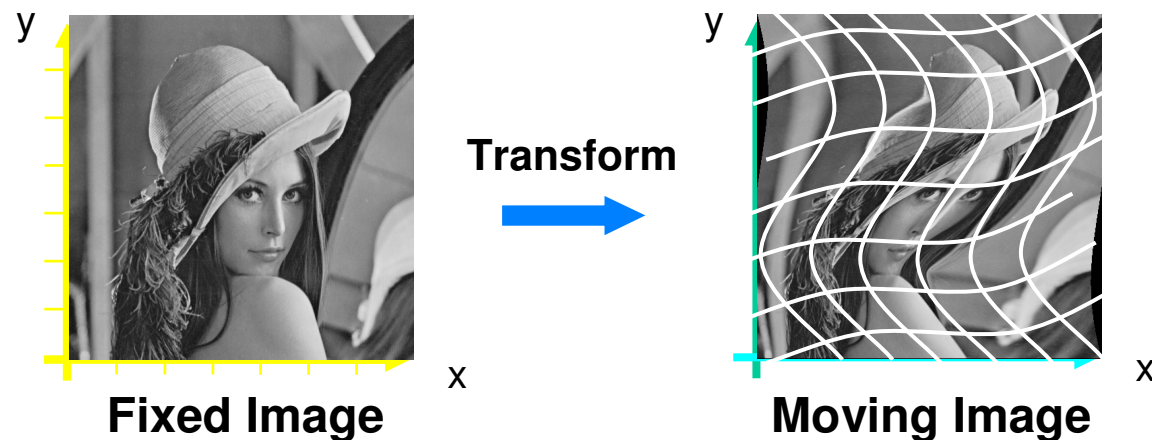
- Translation
- Rotation
- Stretch
- Shear

Non-rigid



- Non-linear, e.g. spline-based, elastic/ fluid models

Deformable B-spline registration



B-splines in Slicer3:

- Similarity measure: mutual information
- Optimizer: itkLBFGSB (limited memory Broyden Fletcher Goldfarb Shannon minimization with simple bounds)



Registration Steps

- Load the image volumes
 - Initial manual rigid transformation
 - Automatic affine registration
 - Automatic deformable B-spline registration
- Initializes transform*
- Initializes transform*



Registration Steps

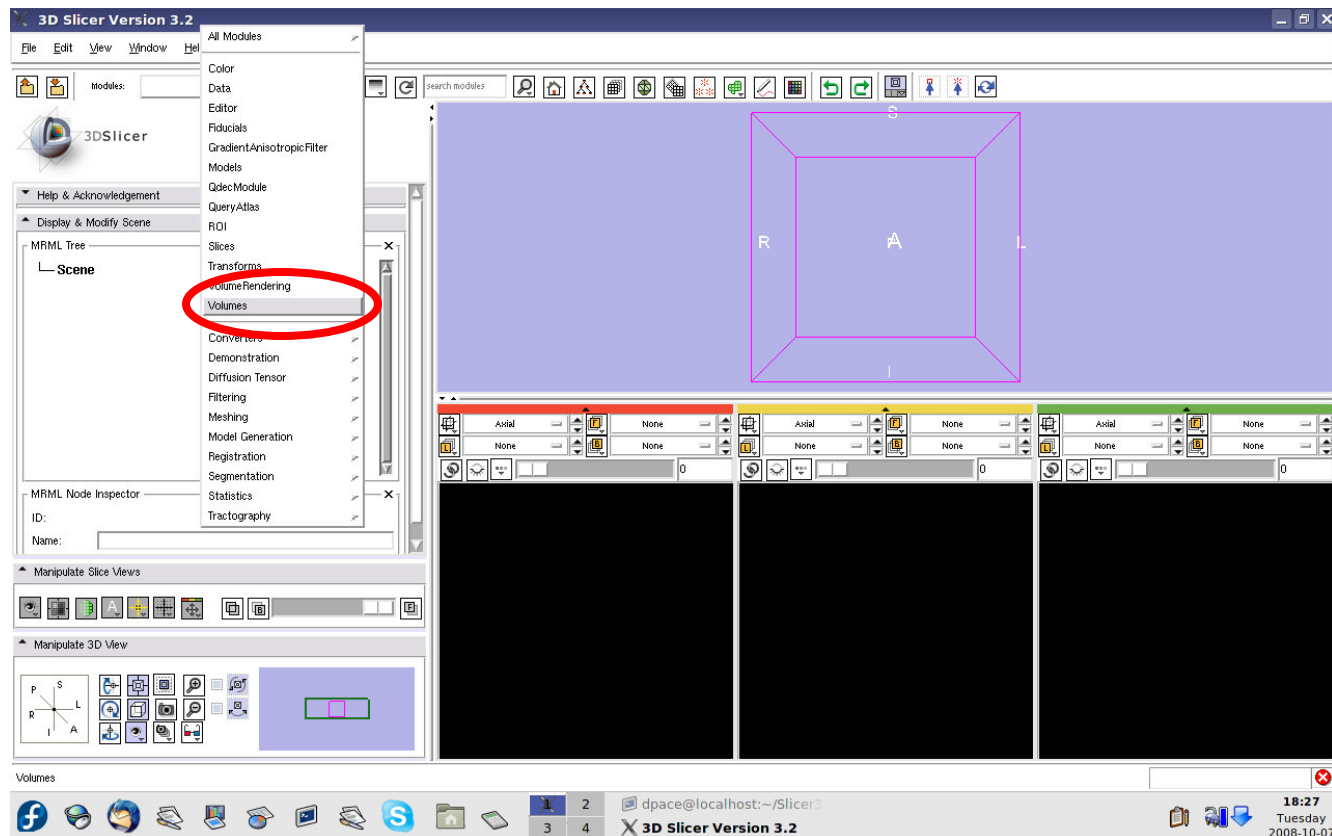
- Load the image volumes
 - Initial manual rigid transformation
 - Automatic affine registration
 - Automatic deformable B-spline registration
- Initializes transform*
- Initializes transform*



Load the image volumes

Load the pre-operative image

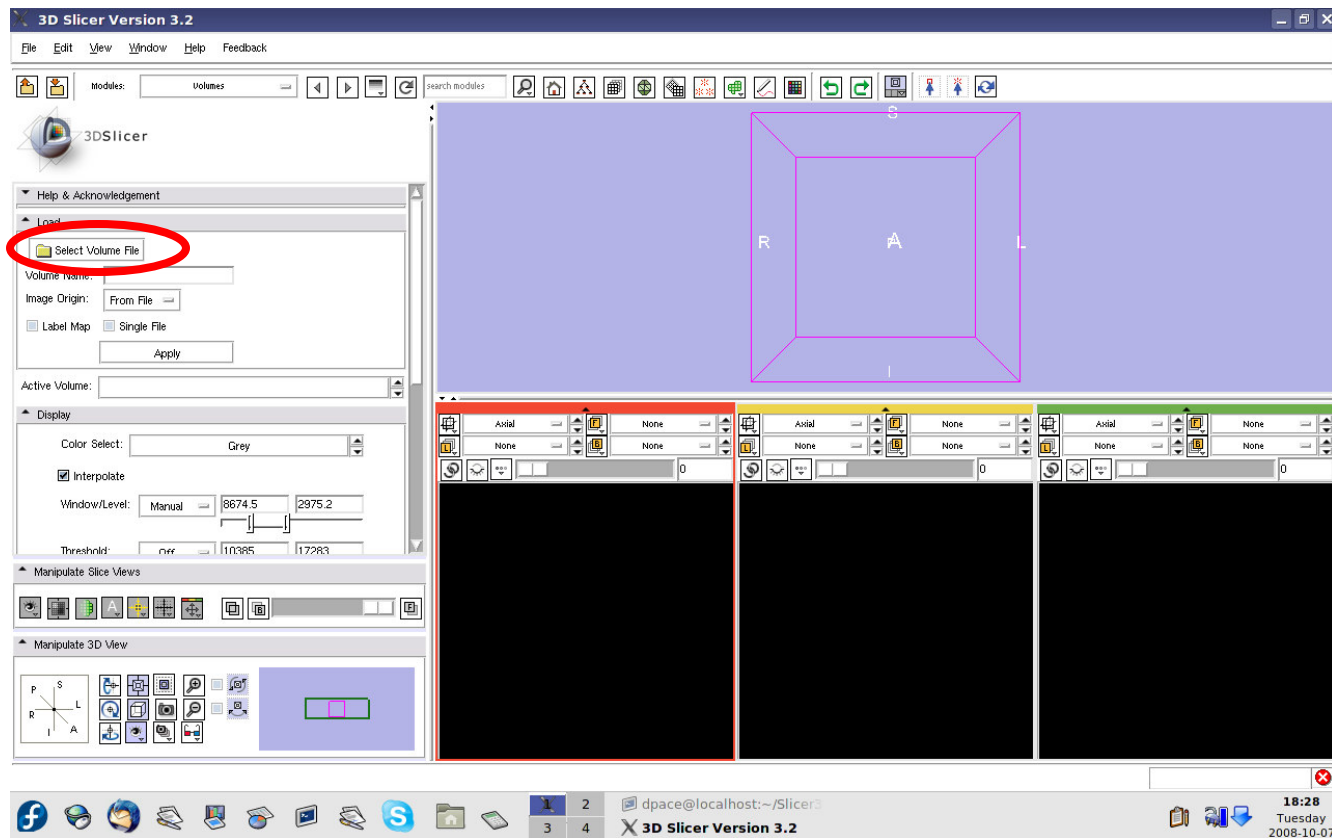
Open the Volumes Module





Load the image volumes

Click on “Select Volume File”

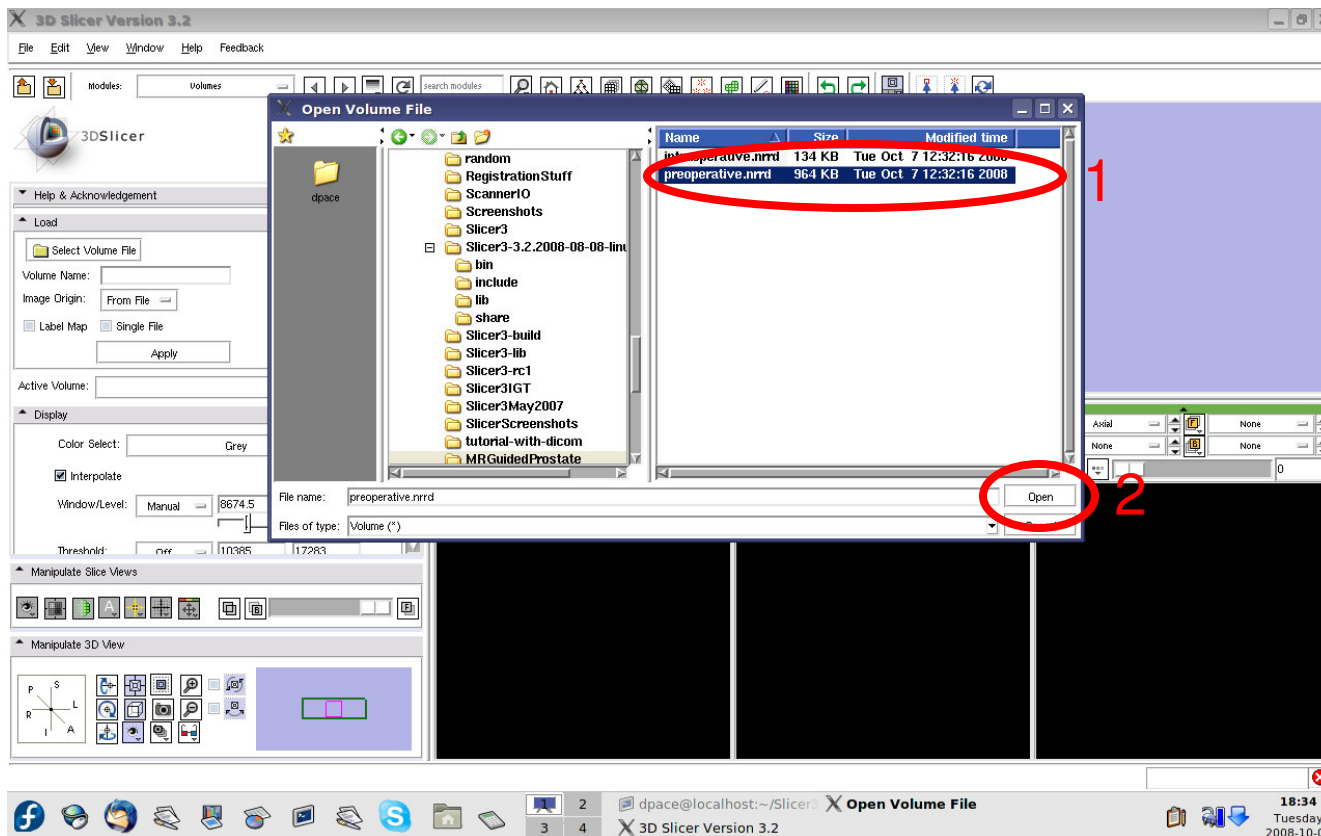


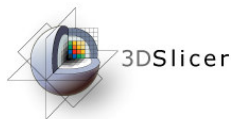


Load the image volumes

Select the pre-operative image:
preoperative.nrrd

Click “Open”





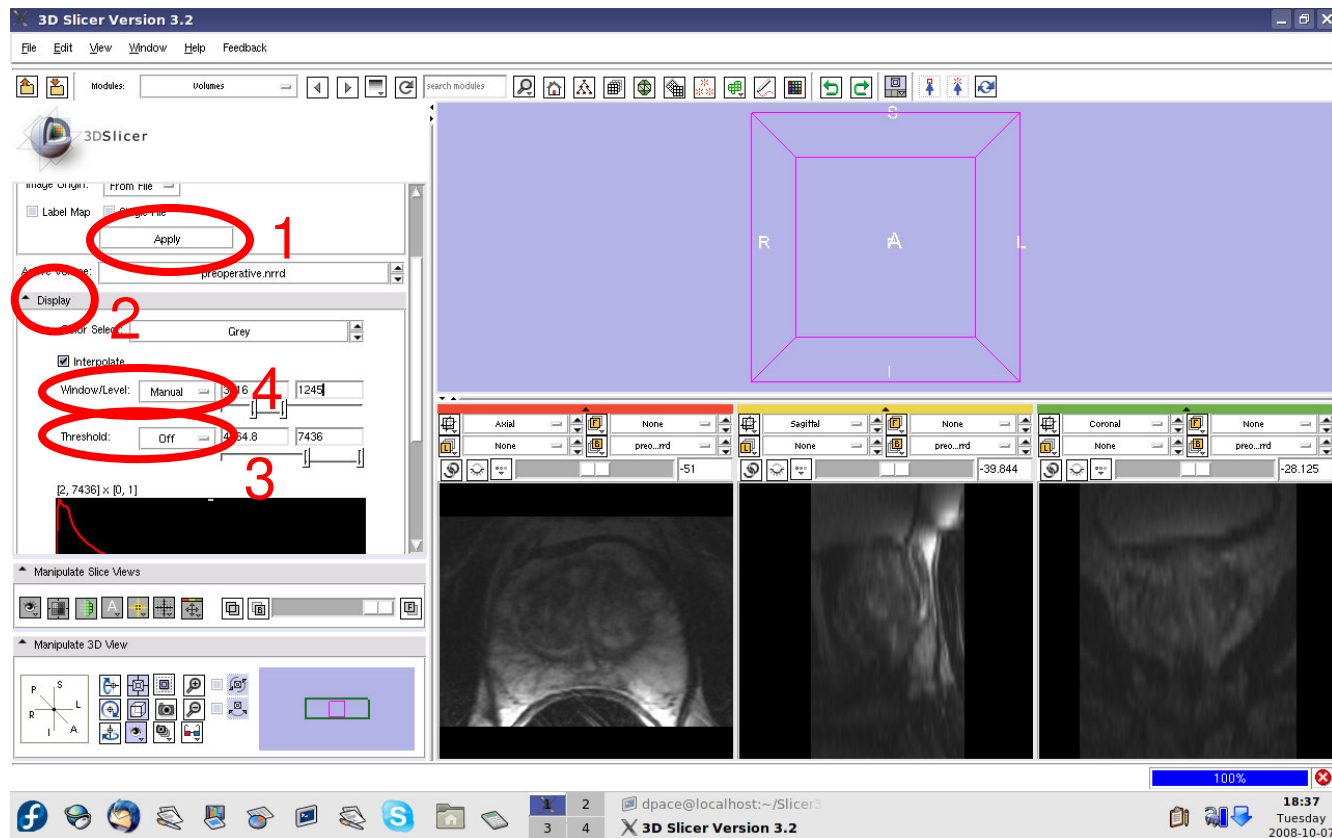
Load the image volumes

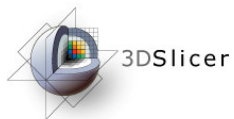
Click “Apply”

Expand the Display tab

Turn thresholding off

Adjust the Window/Level sliders until you can see the image



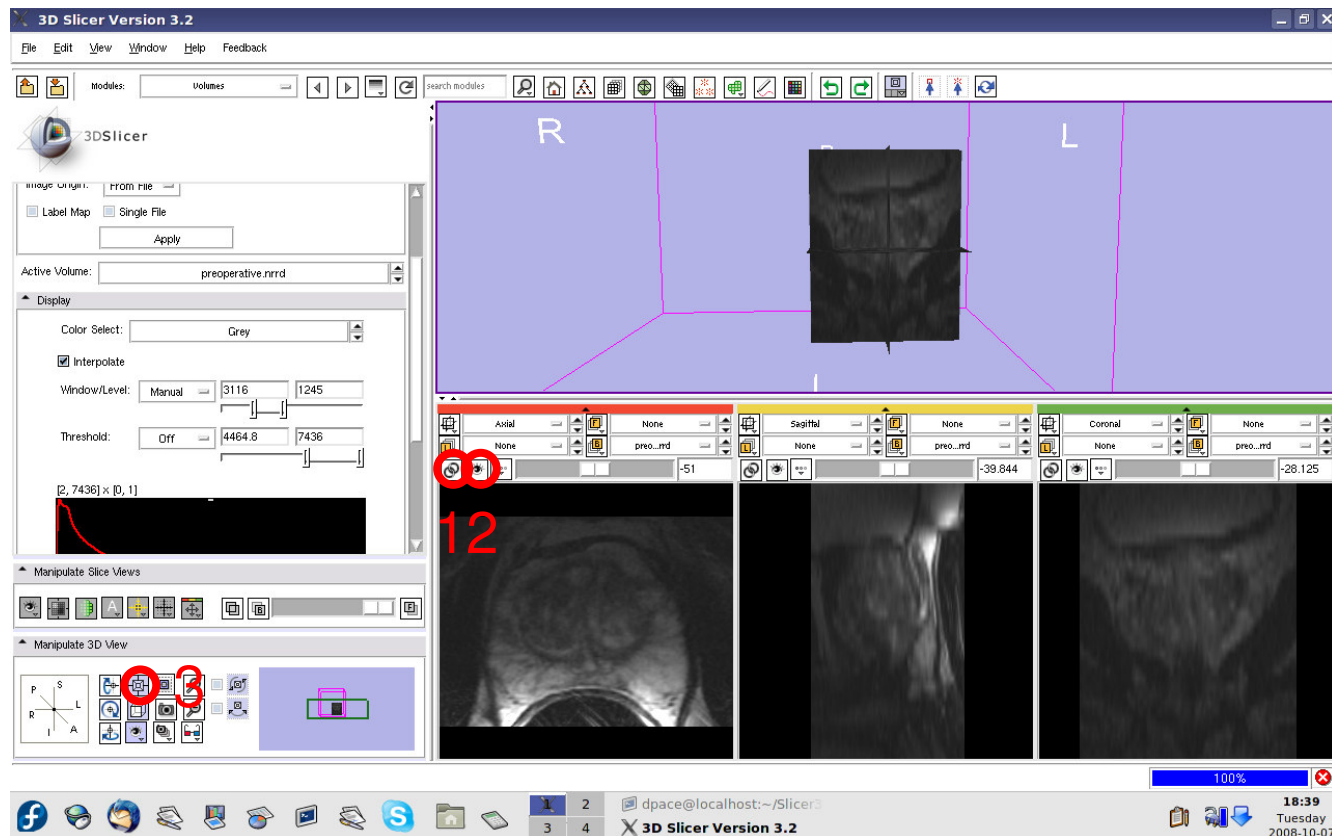


Load the image volumes

Click on the slice control link button

Toggle the slice visibility to see the slices in the 3D viewer

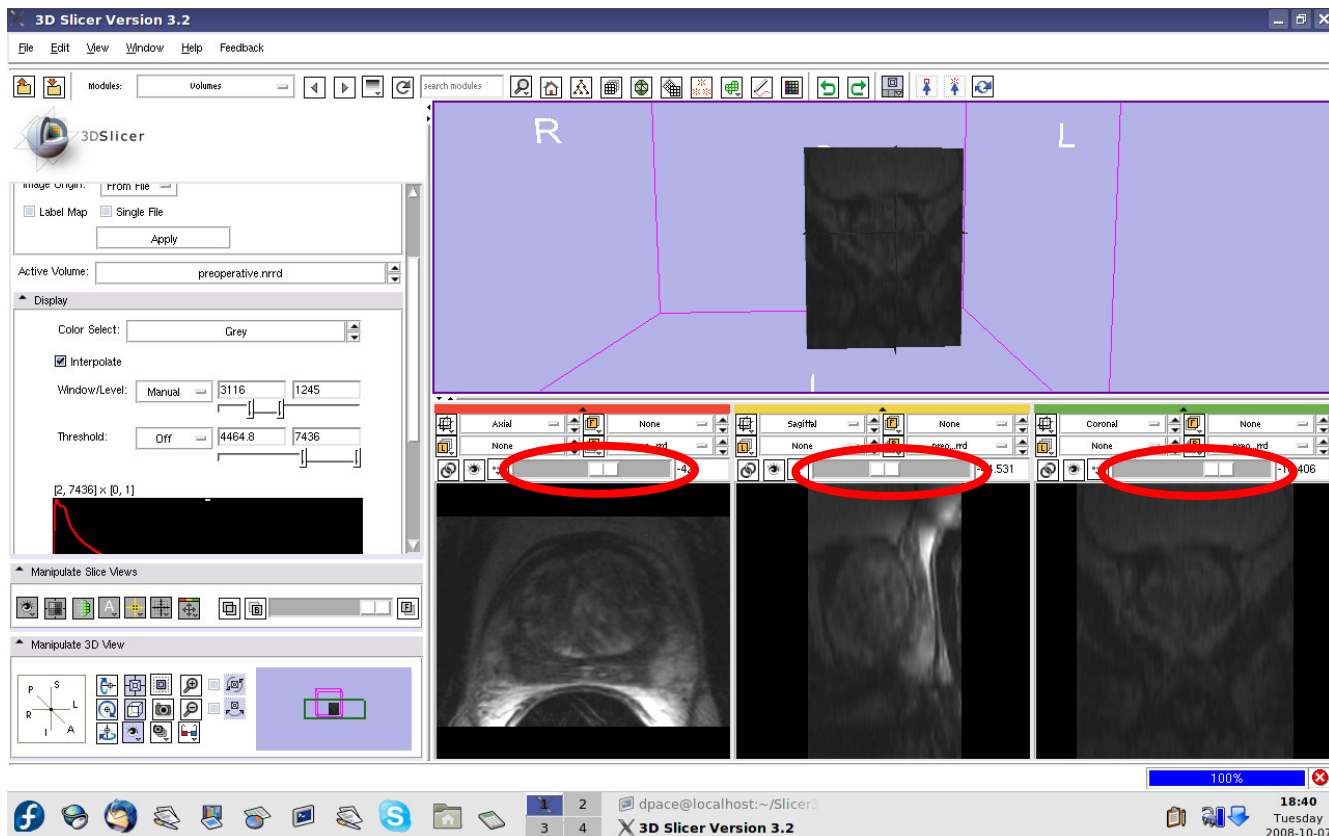
Center the 3D view on the scene and zoom in





Load the image volumes

Use the slice selector sliders to explore the dataset

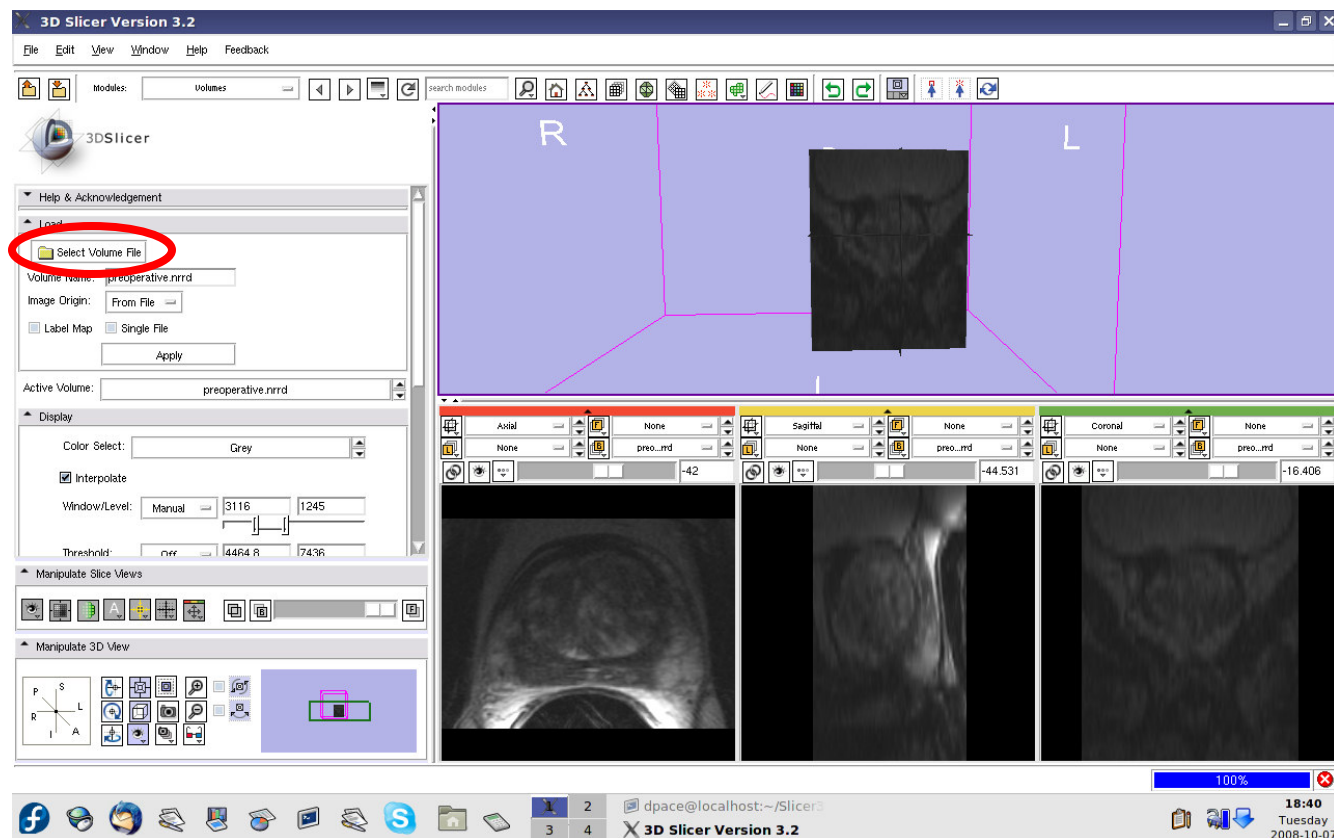




Load the image volumes

Load the intra-operative image

Click on “Select Volume File”

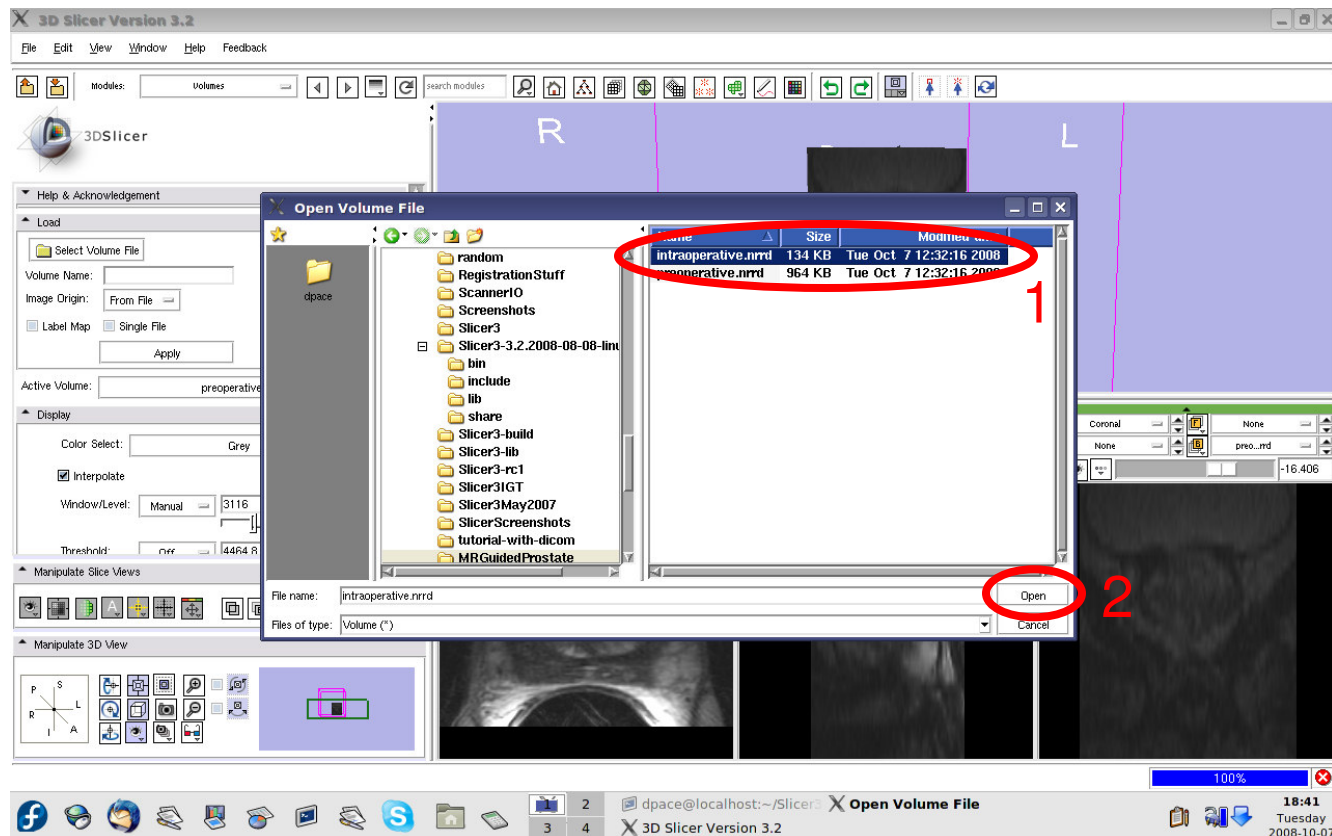




Load the image volumes

Select the
intra-operative
image:
intraoperative.nrrd

Click “Open”





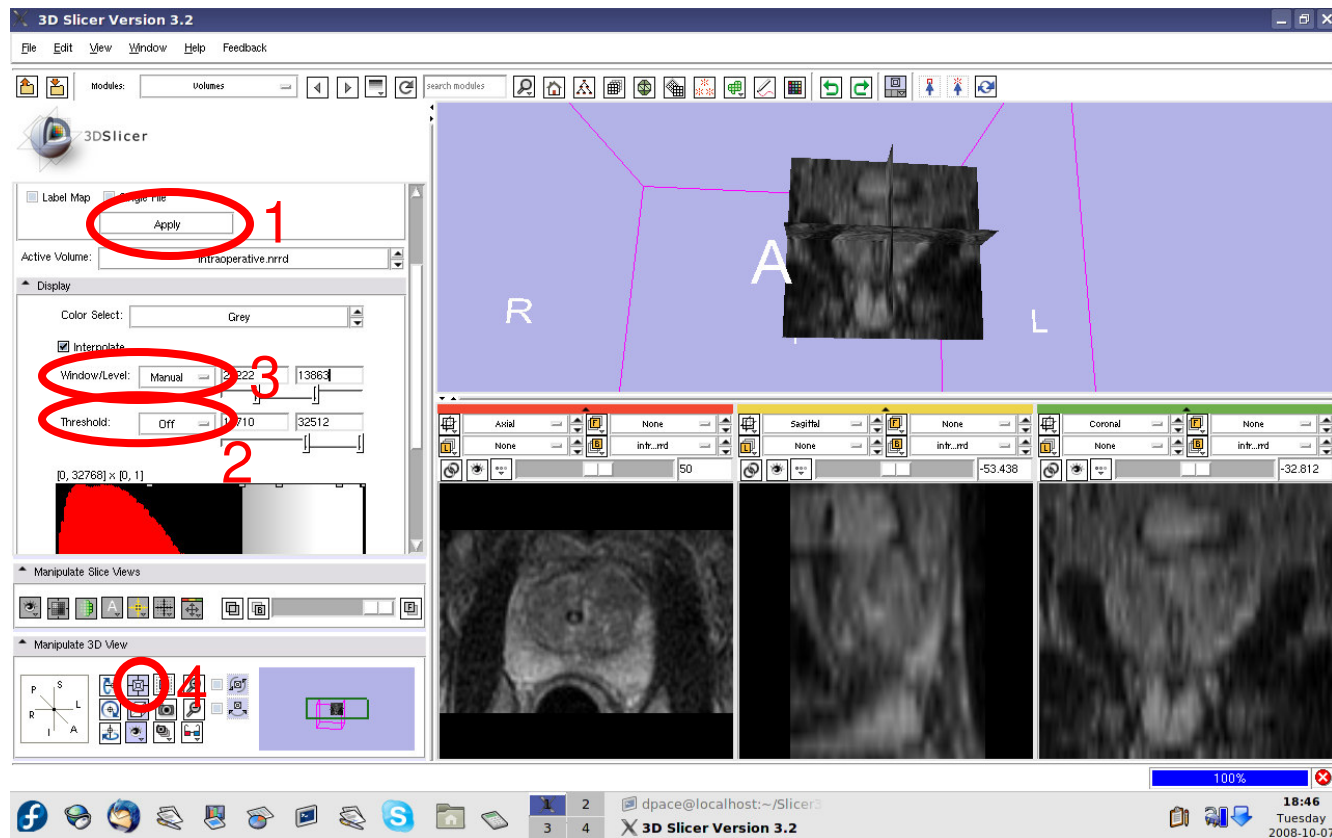
Load the image volumes

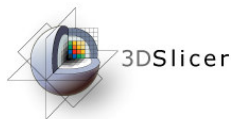
Click “Apply”

Turn thresholding off

Adjust the Window/Level sliders until you can see the image

Center the 3D view on the scene



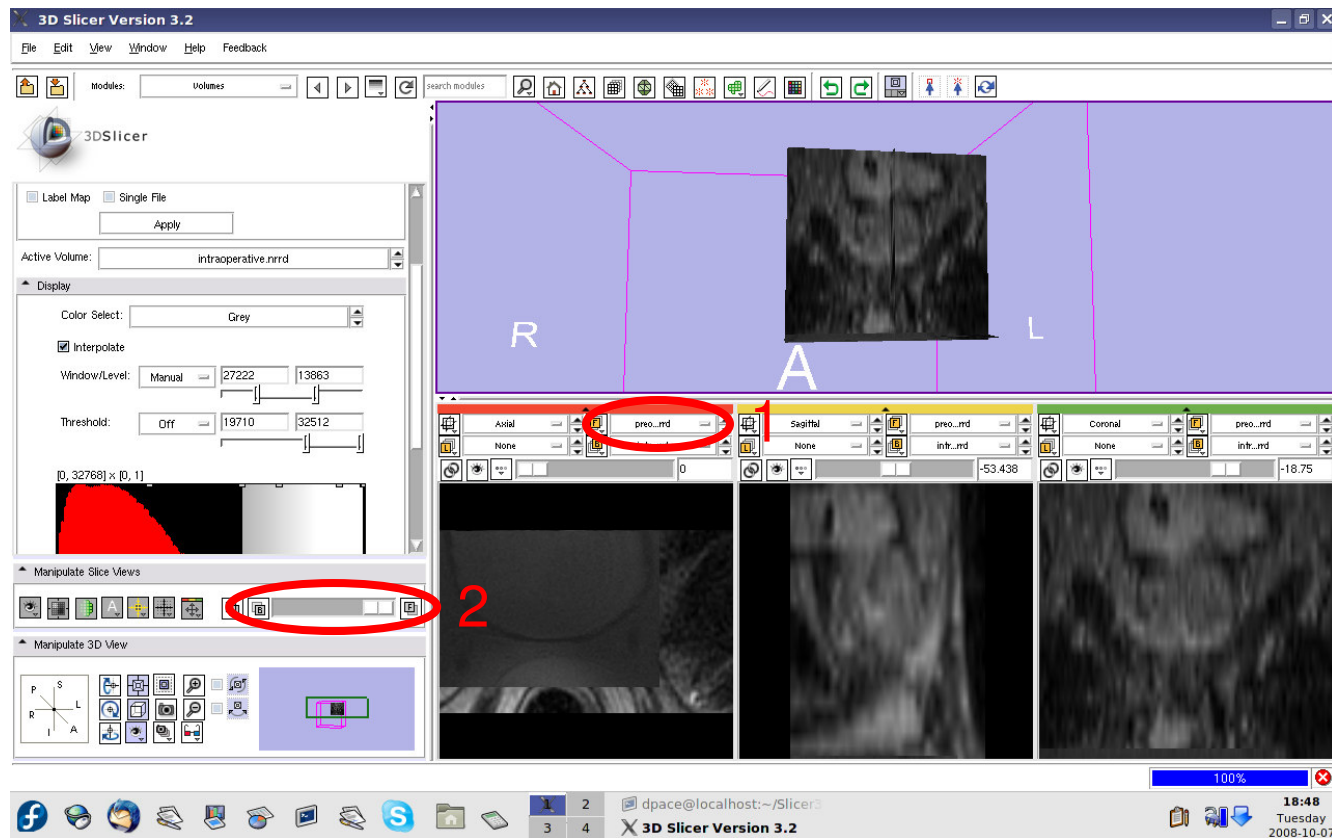


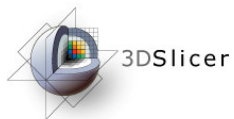
Load the image volumes

Note that the images are not aligned

Set the foreground to the pre-operative image

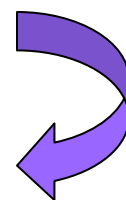
Scale between the foreground and background





Registration Steps

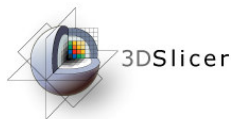
- Load the image volumes
- Initial manual rigid transformation
- Automatic affine registration
- Automatic deformable B-spline registration



*Initializes
transform*

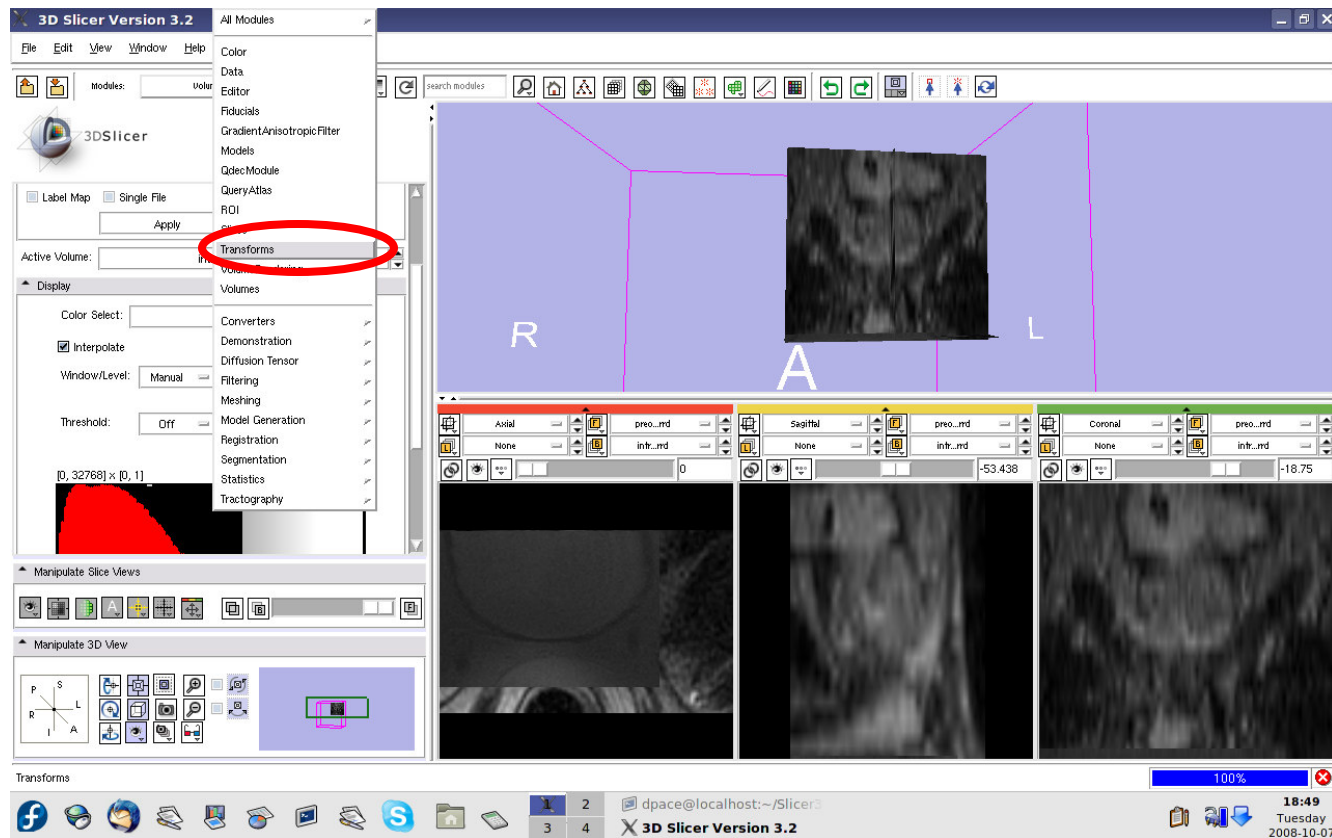


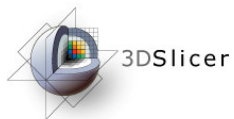
*Initializes
transform*



Manual rigid transformation

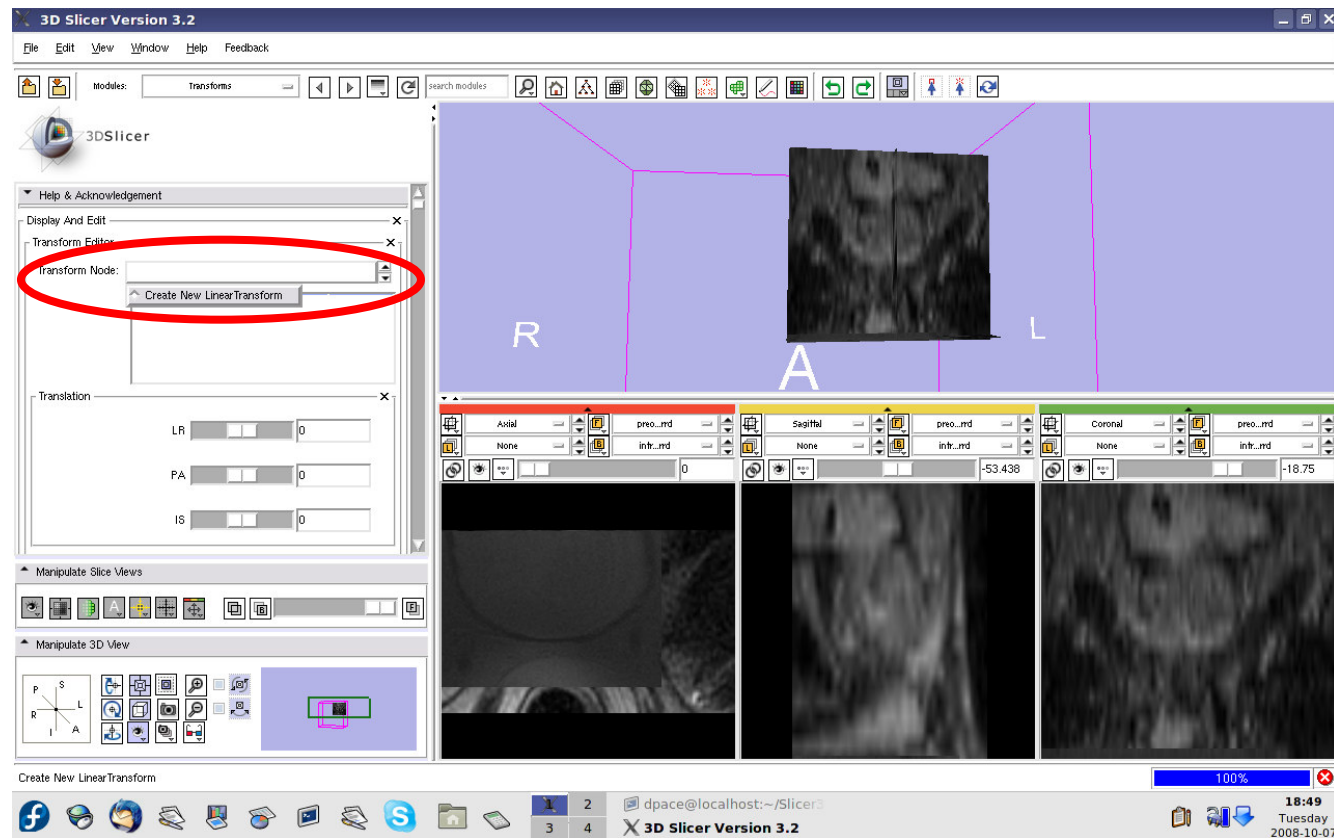
Open the
Transforms
module





Manual rigid transformation

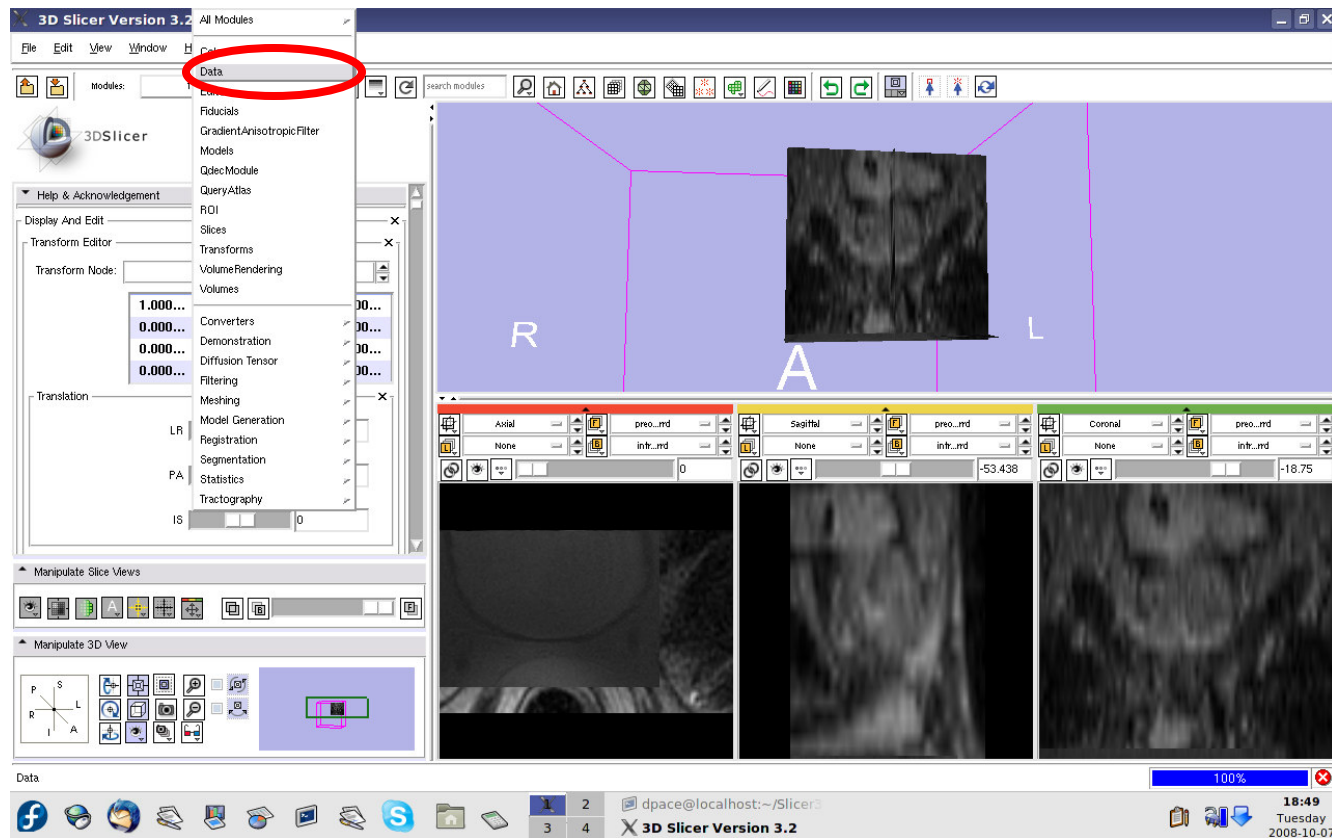
Create a new linear transform





Manual rigid transformation

Open the Data module

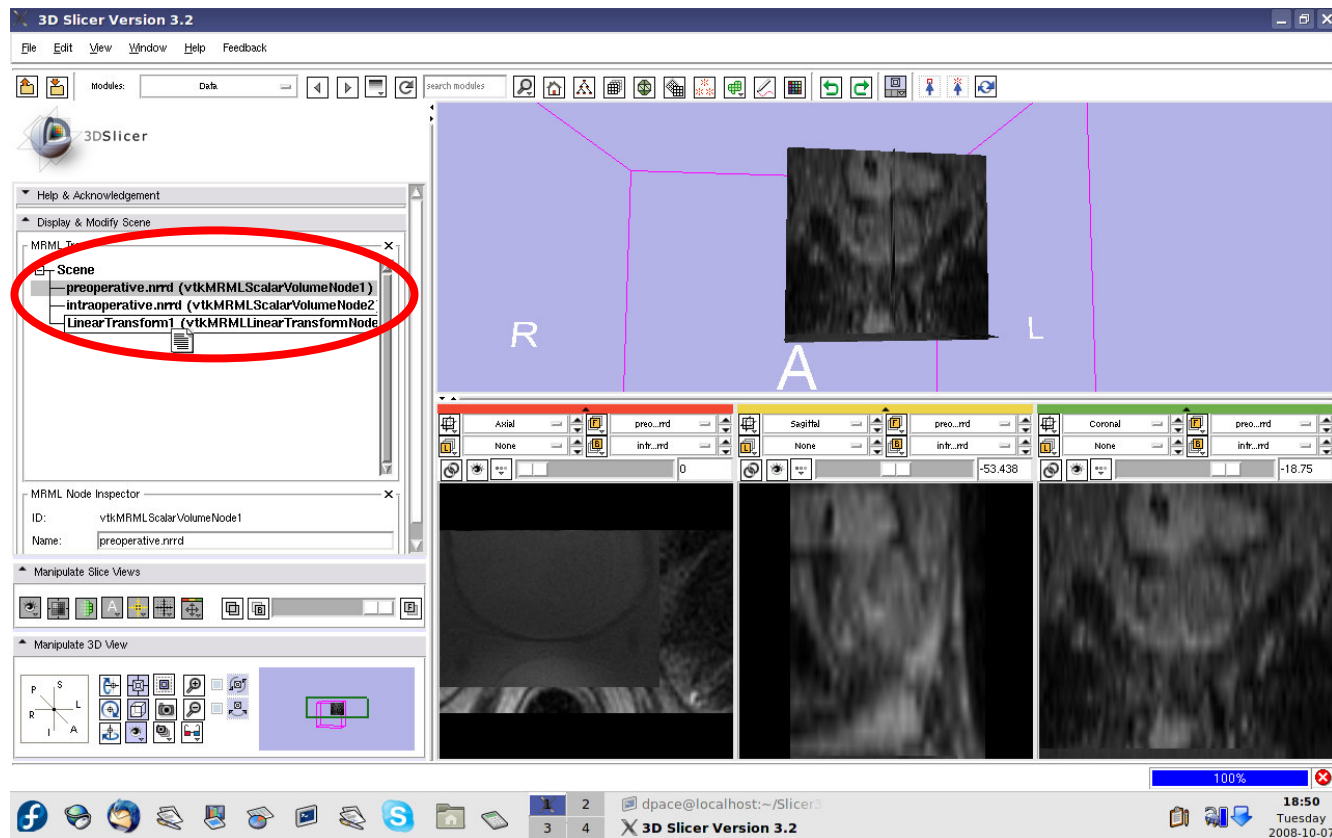




Manual rigid transformation

Apply the manual rigid transformation to the pre-operative image

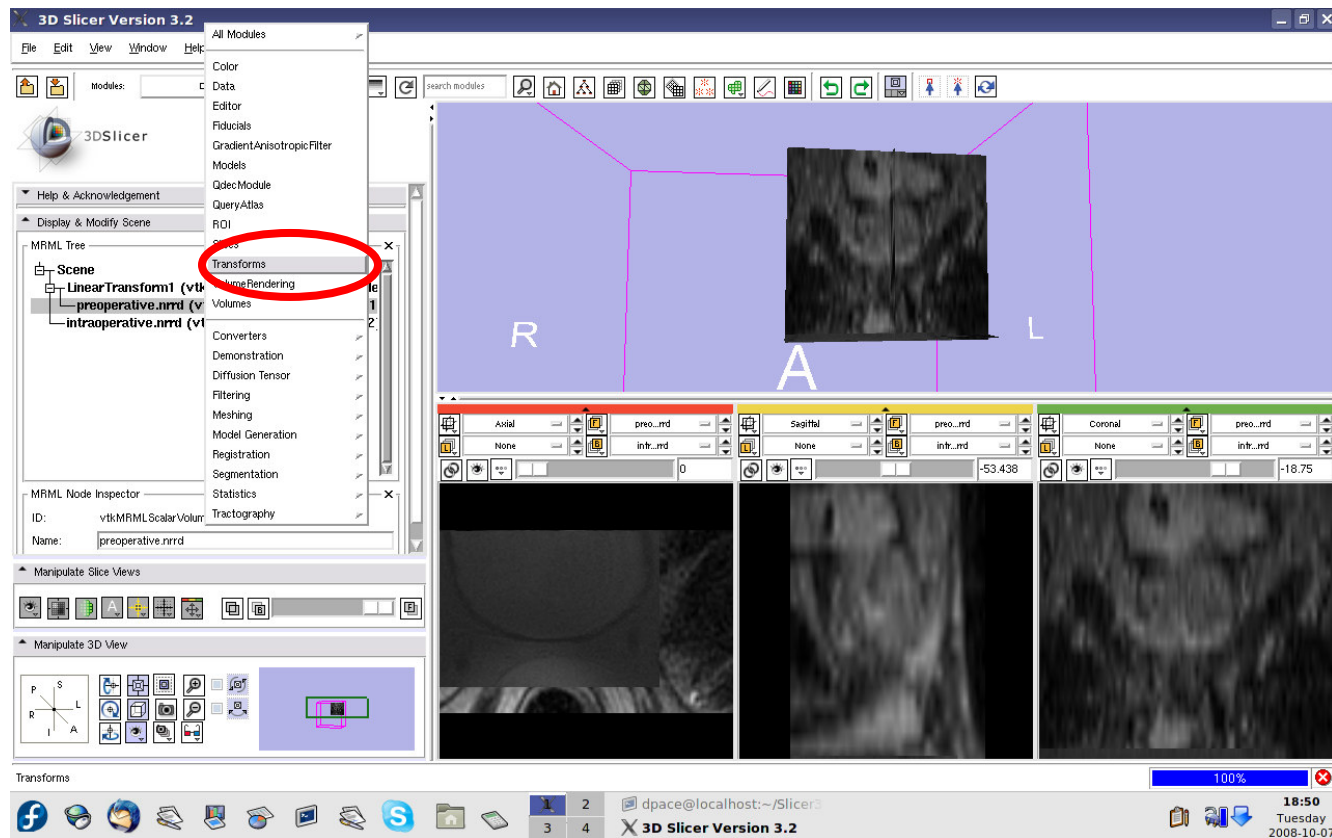
Drag the pre-operative image under the Linear Transform1 node





Manual rigid transformation

Open the
Transforms
module

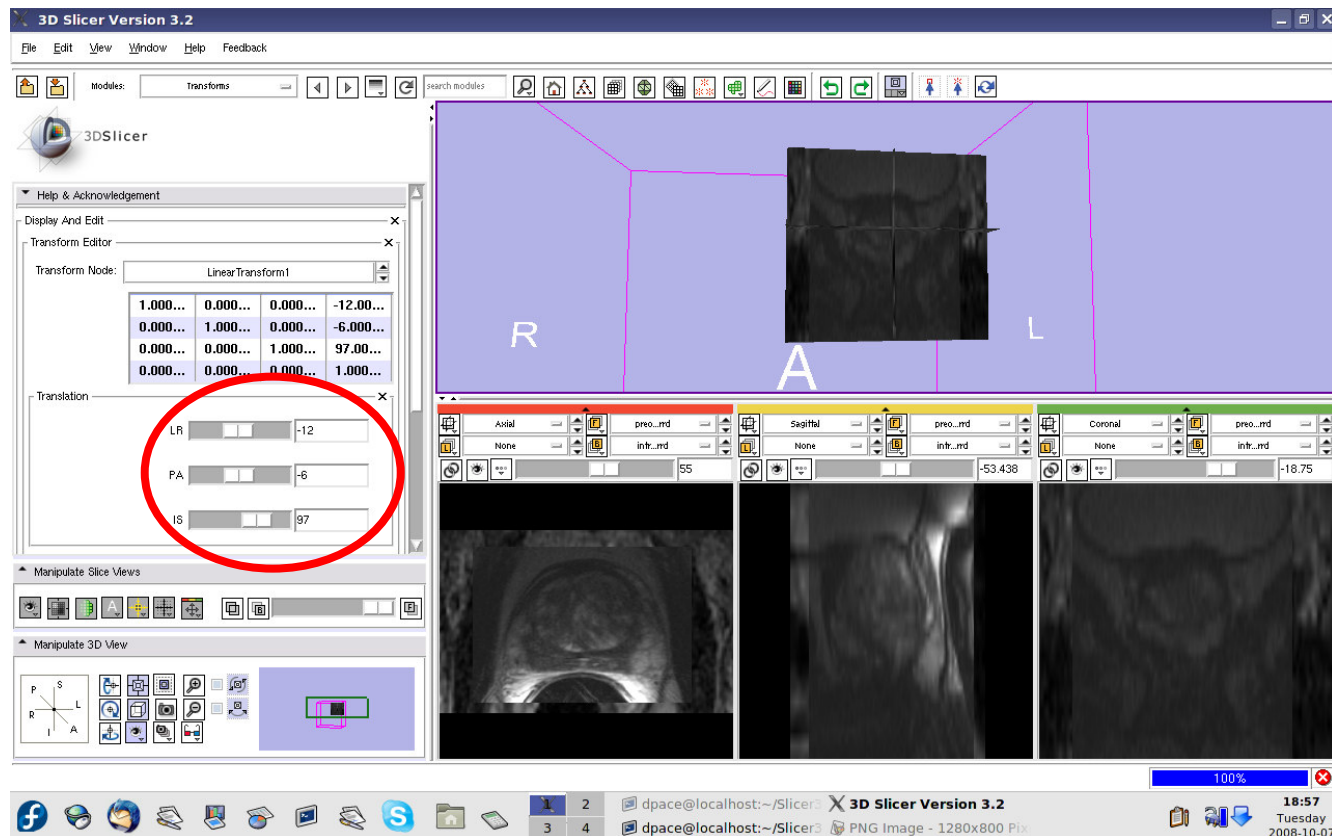


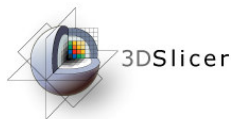


Manual rigid transformation

Manually adjust the translation and rotation parameters to align the two image volumes

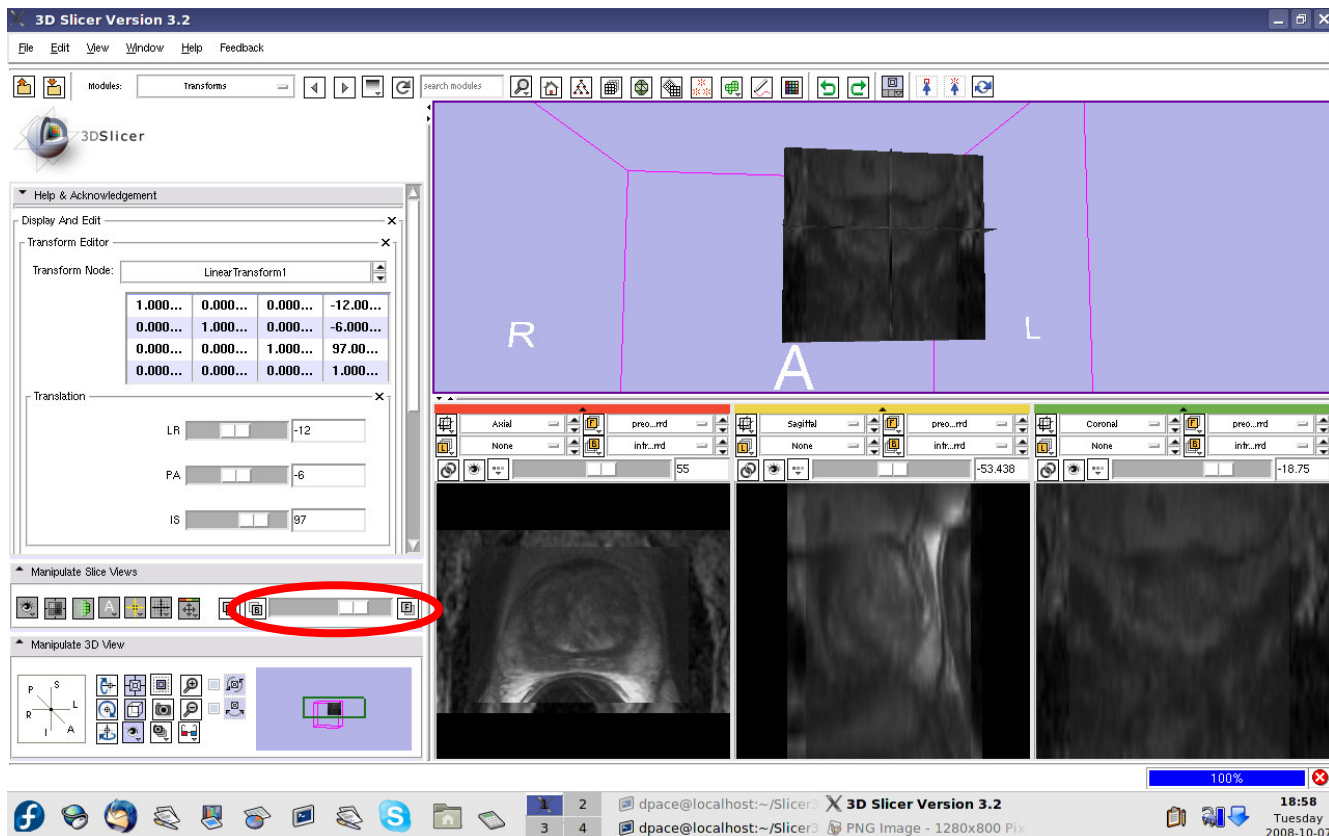
Recommended:
Trans. LR: -12
Trans. PA: -6
Trans. IS: 97
No rotation

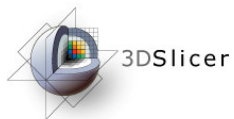




Manual rigid transformation

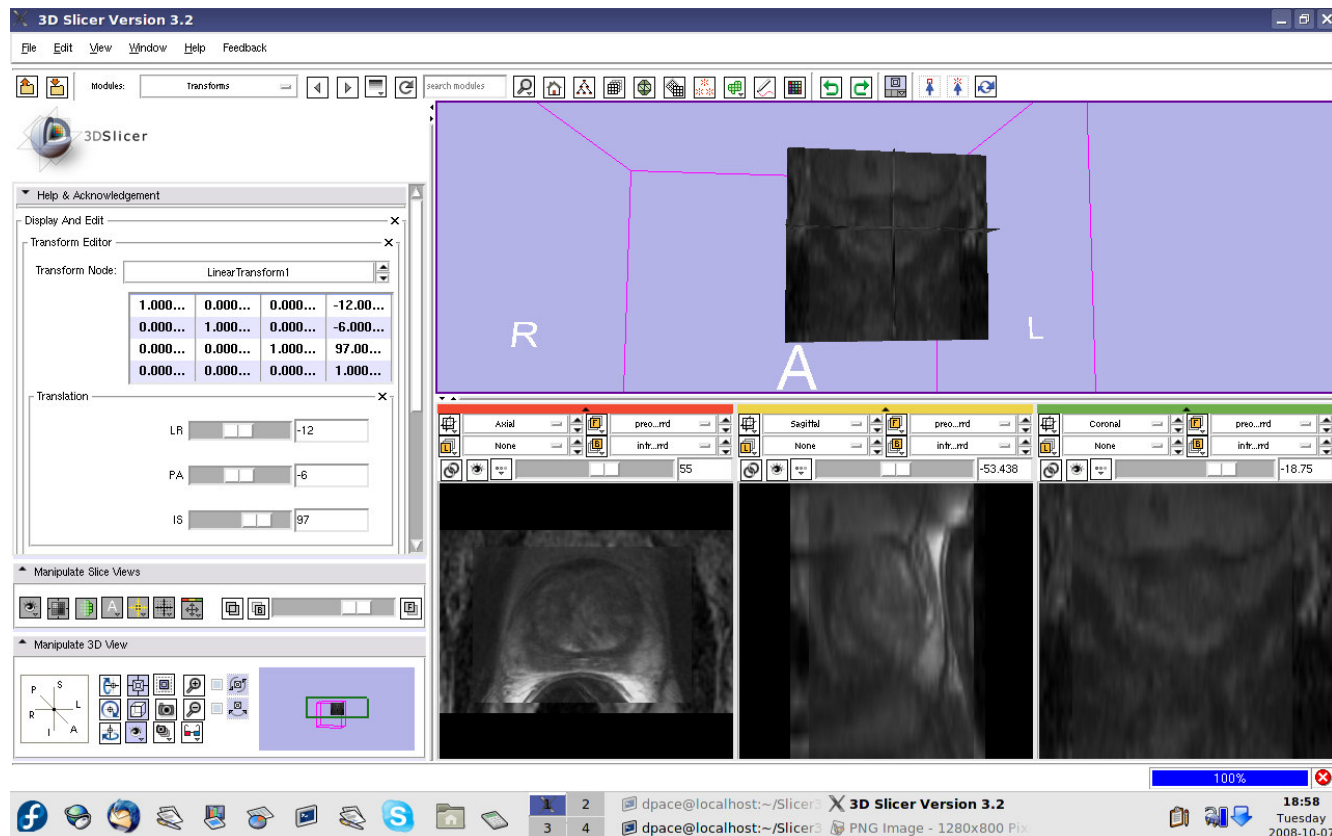
Scale between the foreground and background to evaluate the alignment

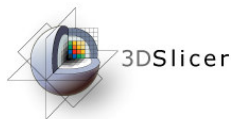




Manual rigid transformation

The initial transformation “pushes” the pre-operative image onto the intra-operative image, but Slicer’s registration algorithm expects the inverse

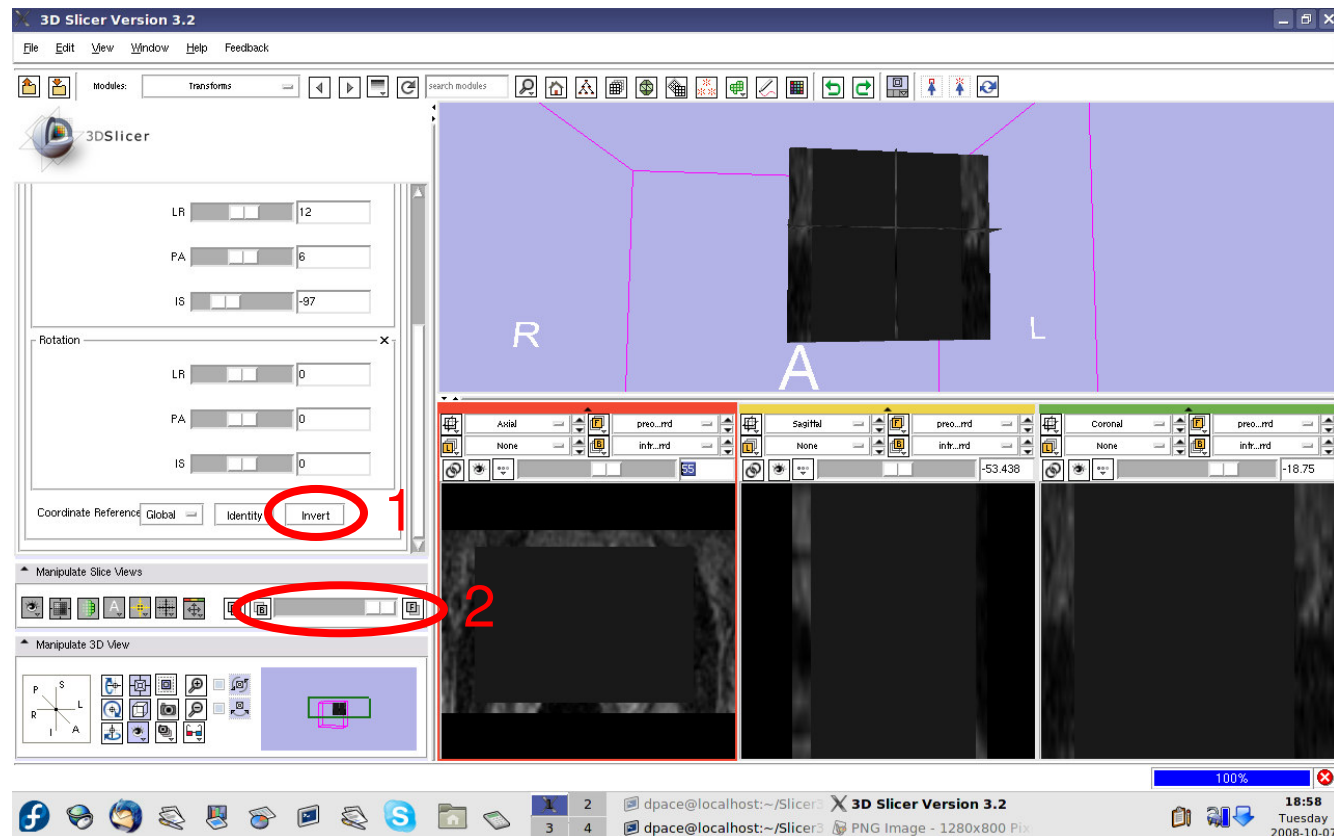


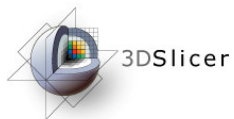


Manual rigid transformation

Click on the
“Invert” button

Scale between
the foreground
and background
- note that the
two images are
no longer
aligned





Registration Steps

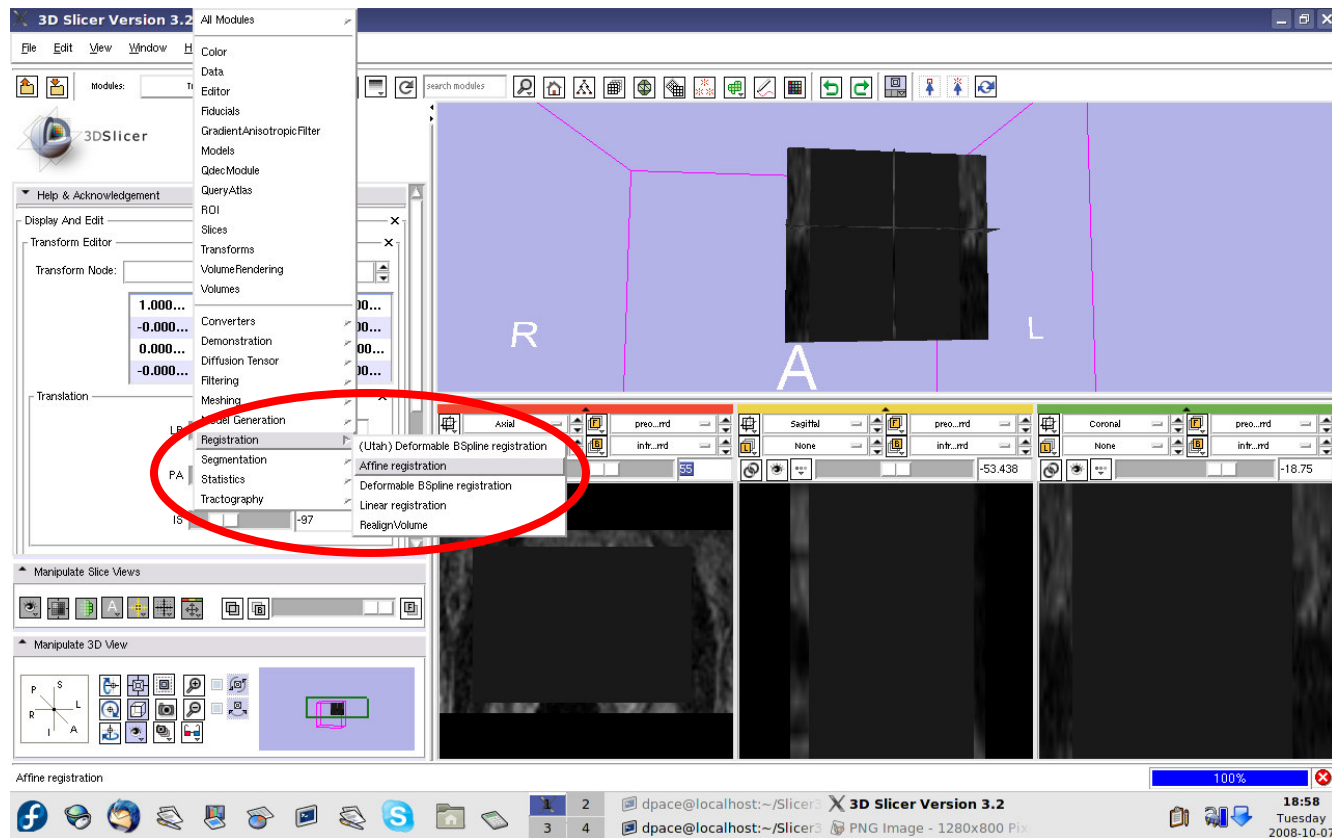
- Load the image volumes
 - Initial manual rigid transformation
 - Automatic affine registration
 - Automatic deformable B-spline registration
- Initializes transform*
- Initializes transform*



Affine registration

Perform the affine registration

Open the Affine Registration module

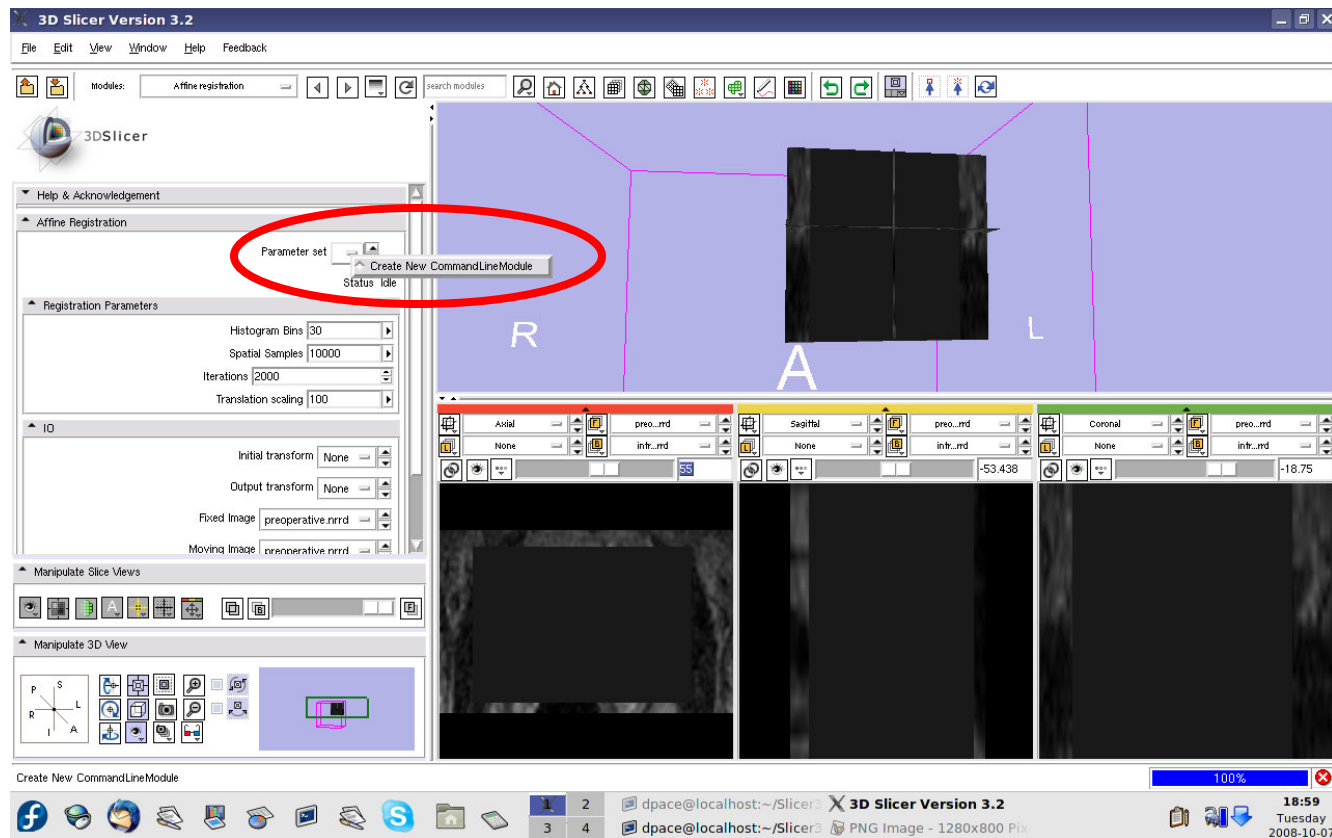




Affine registration

Create a new affine registration transform

You do not need to change any of the registration parameters

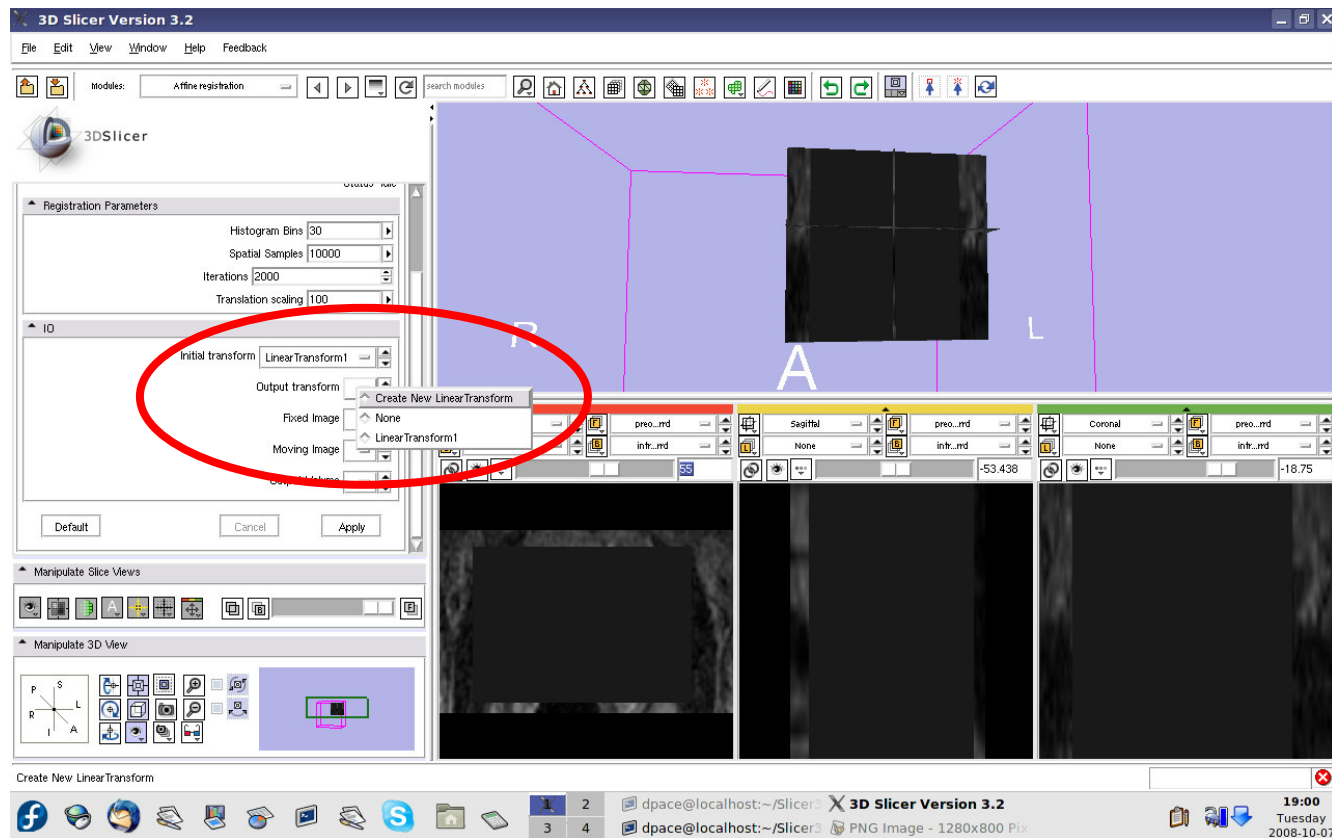




Affine registration

Initial transform:
Linear Transform1

Output transform:
Create new linear transform



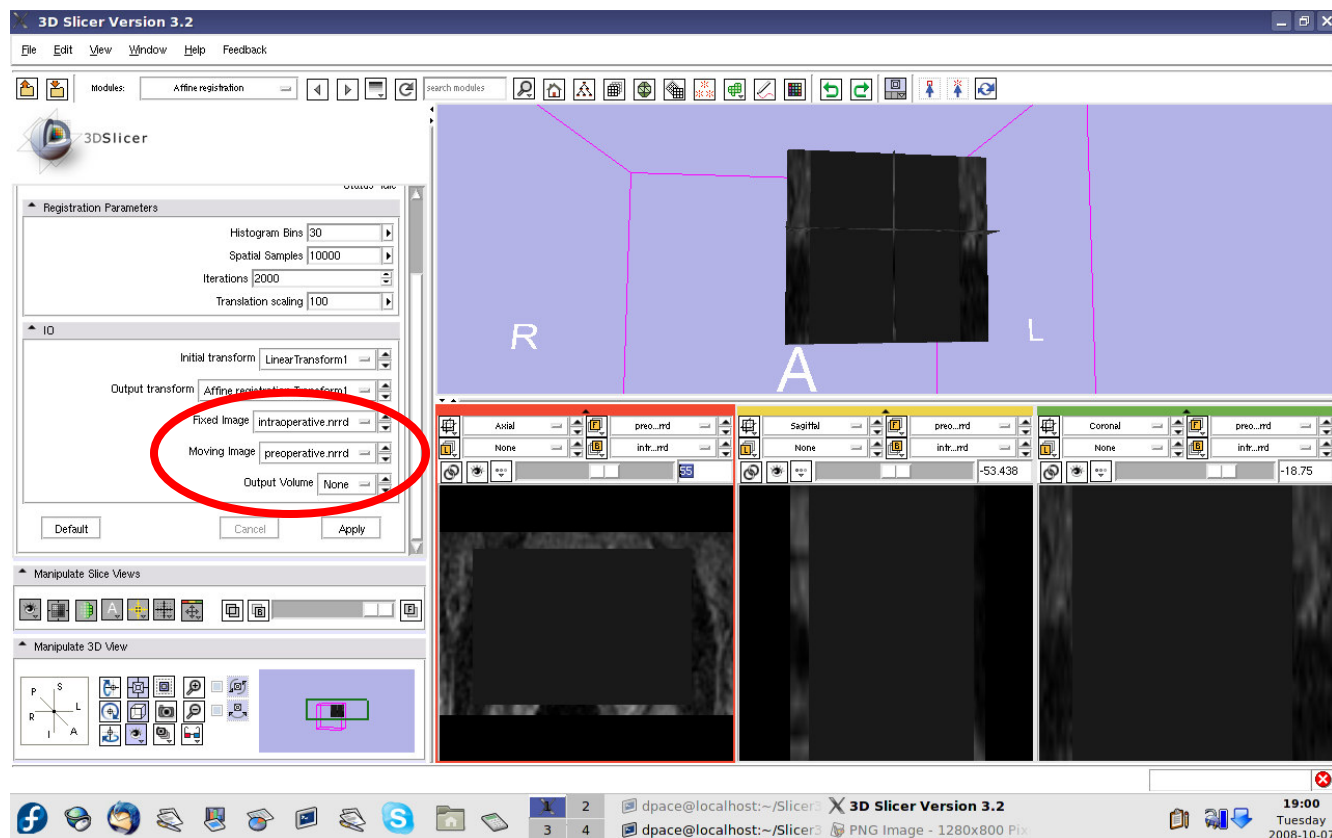


Affine registration

Fixed image:
intra-operative

Moving image:
pre-operative

**Output
Volume:**
None

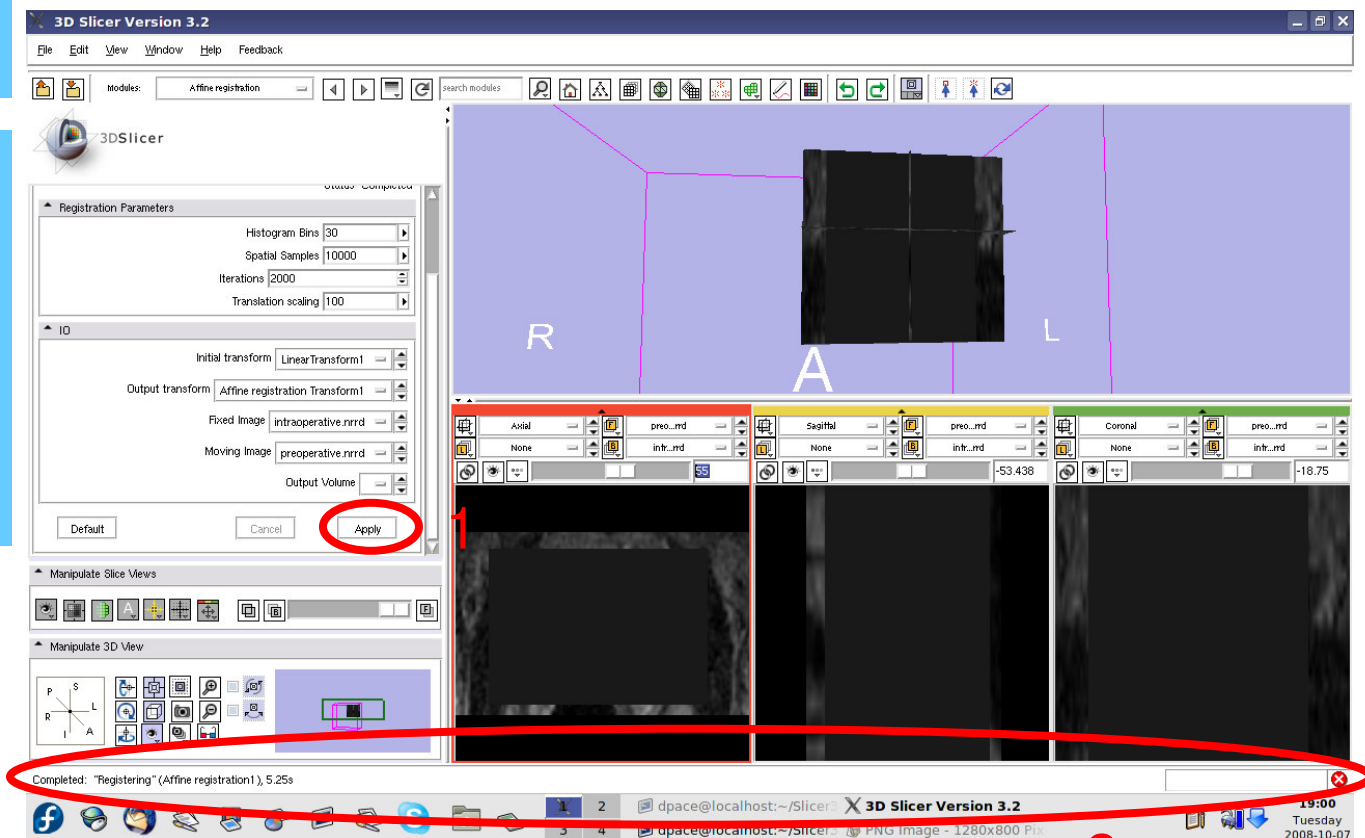


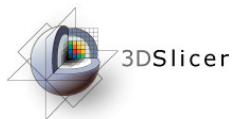


Affine registration

Click “Apply”

View the progress bar and wait until it says “Completed”

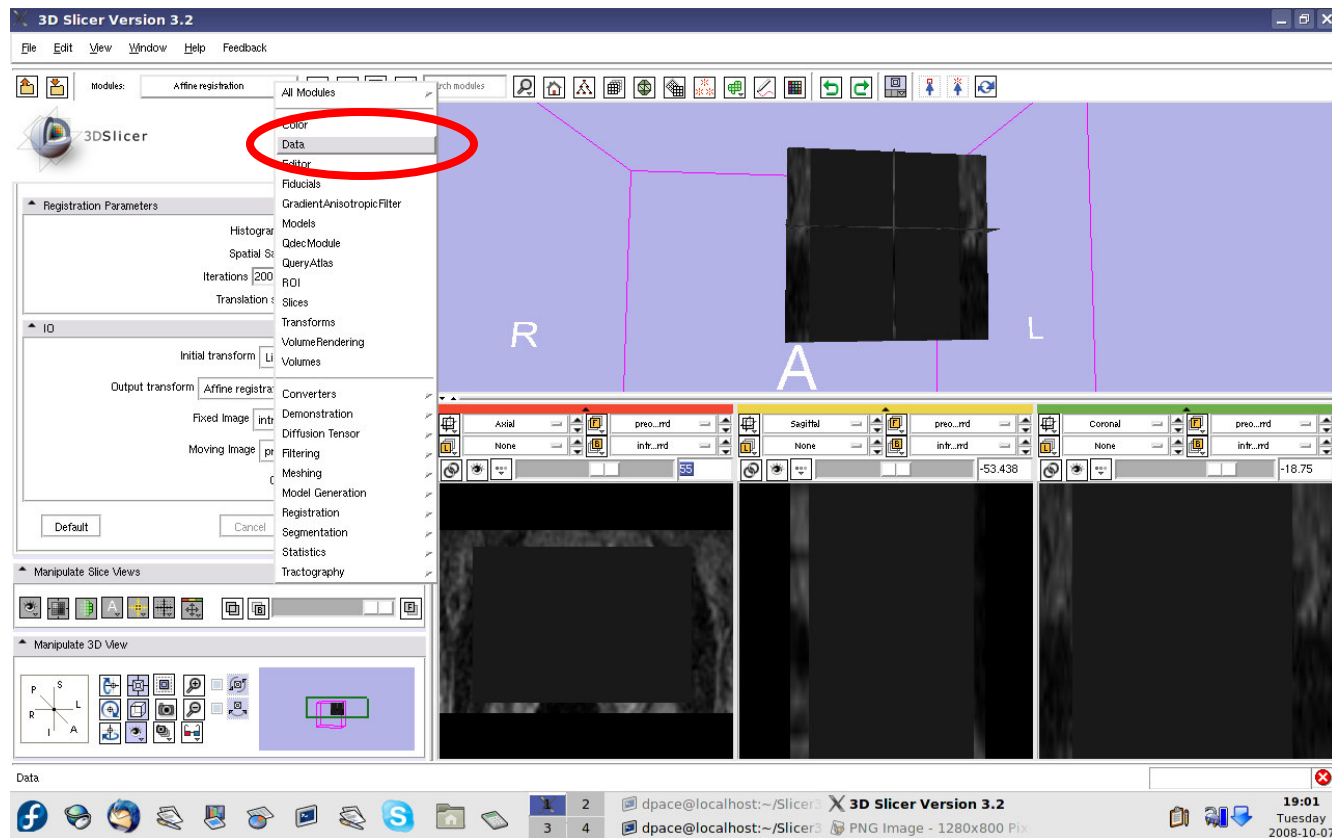


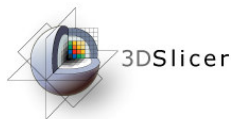


Affine registration

Evaluate the affine registration

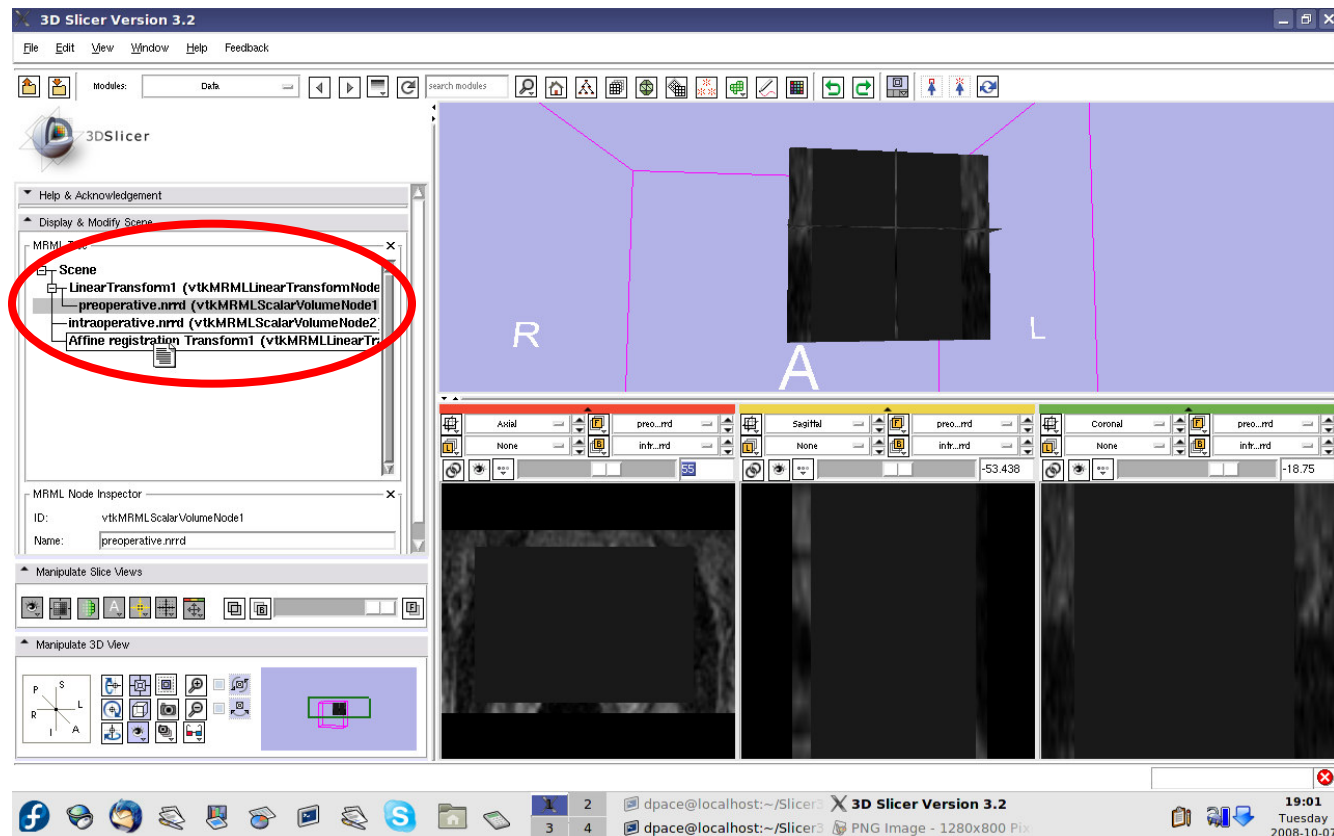
Open the Data module

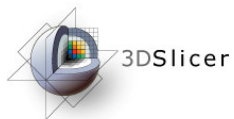




Affine registration

Drag the pre-operative image under the Affine registration Transform1 node

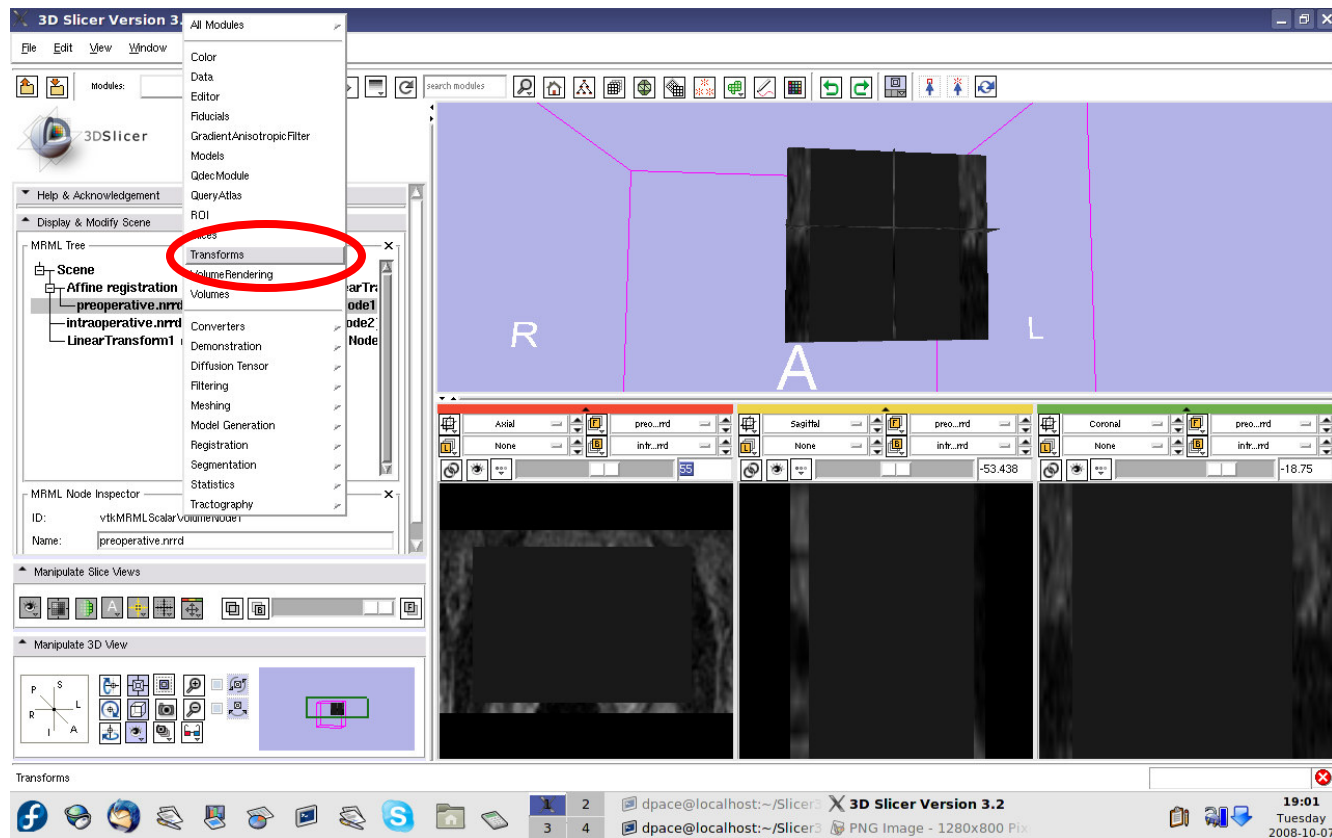




Affine registration

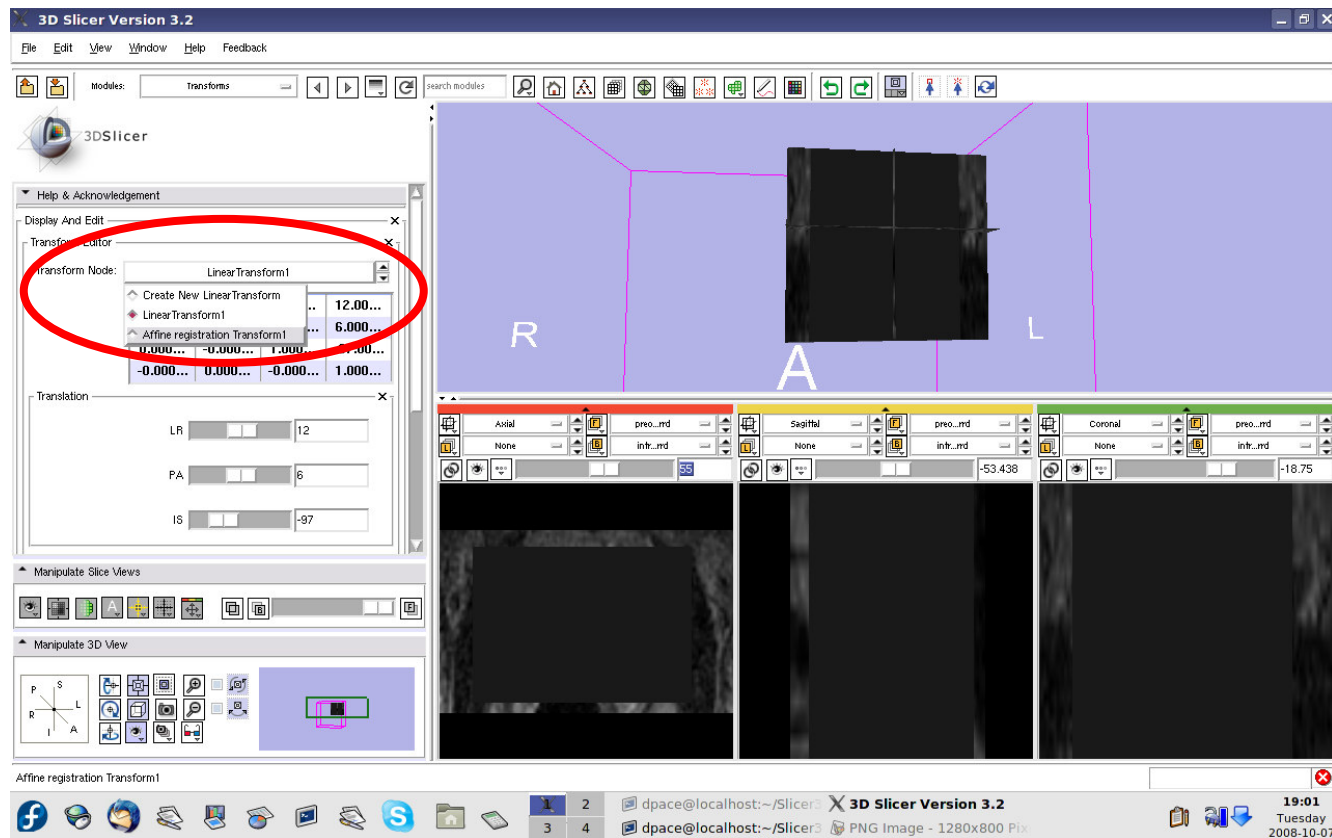
In order to evaluate the affine registration, the transform must be inverted back

Open the Transforms module



Change the transform node to the affine registration transform

Note that the affine transform is different from the rigid transform that we manually specified

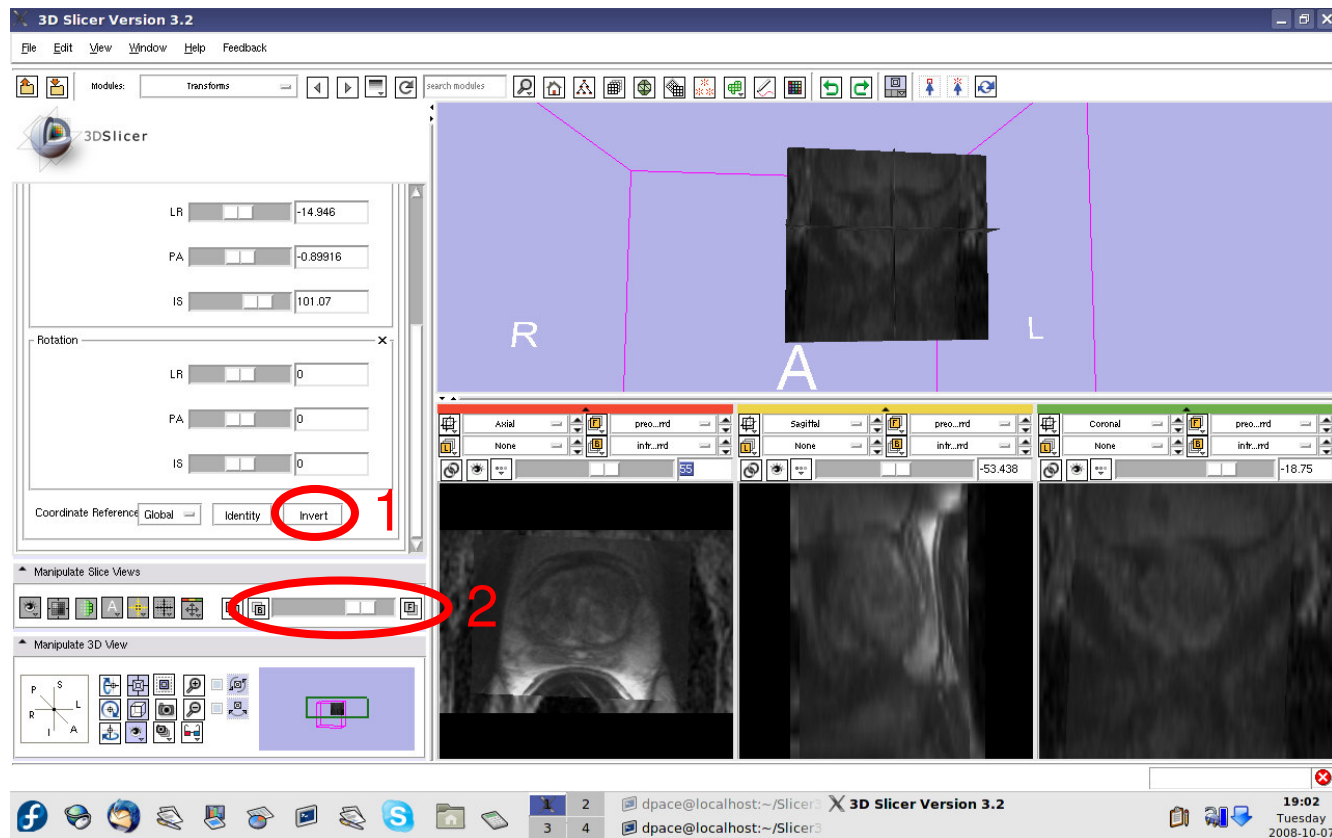




Affine registration

Click on the
“Invert” button

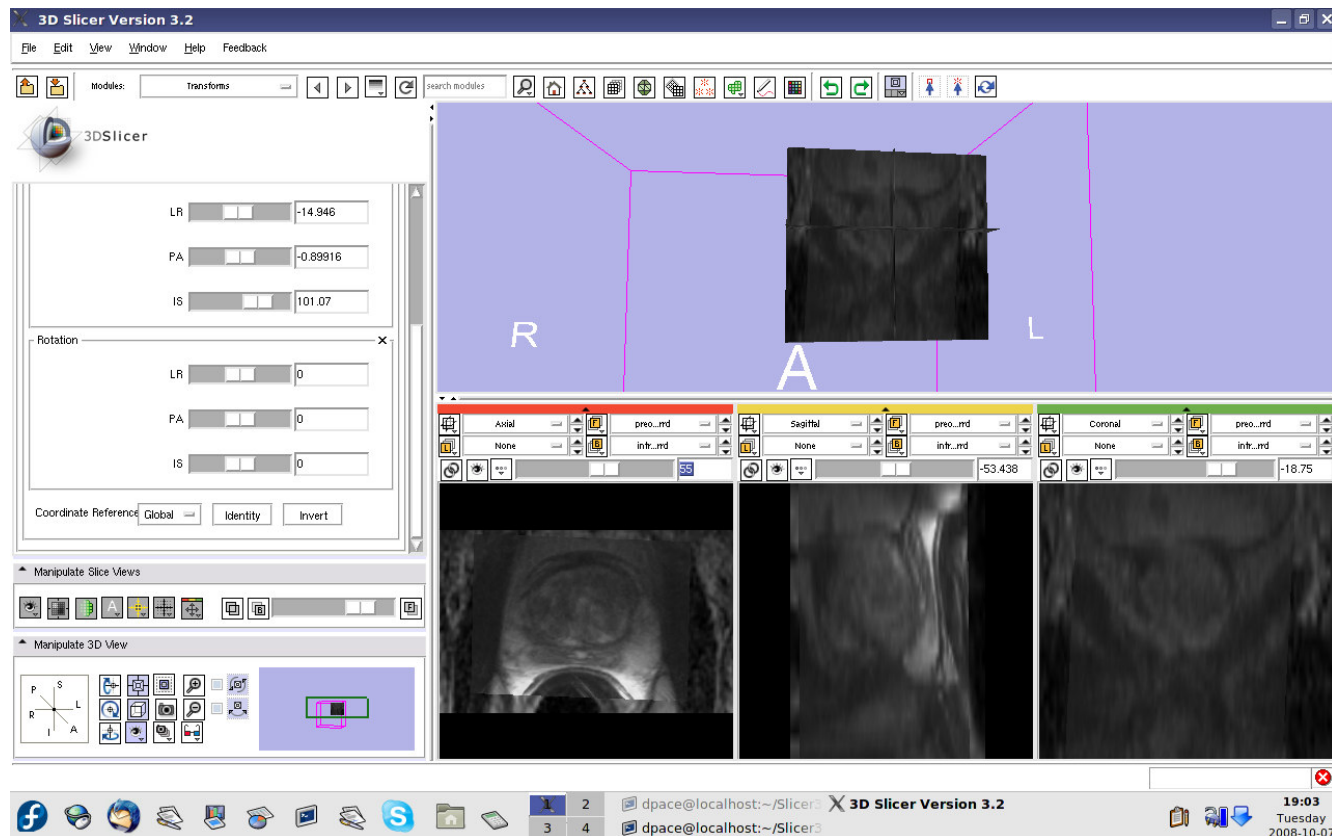
Scale between
the foreground
and background
to evaluate the
alignment





Affine registration

Now that we've evaluated the affine transform, it must be inverted before it can be used to initialize the deformable B-spline registration

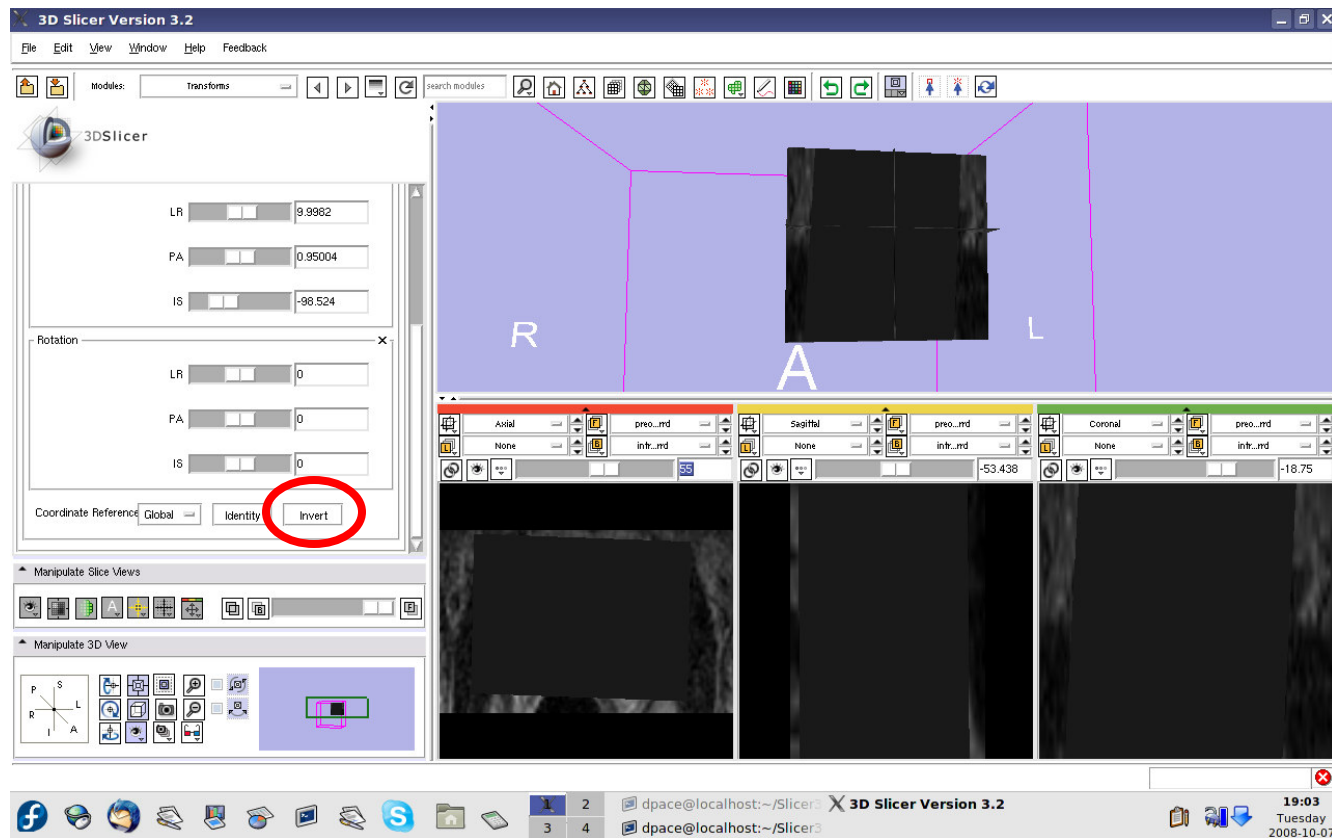




Affine registration

Click on the
“Invert” button

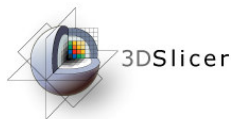
We are back to
the original
transform given
by the affine
registration:
note that once
again, the
images are not
aligned





Registration Steps

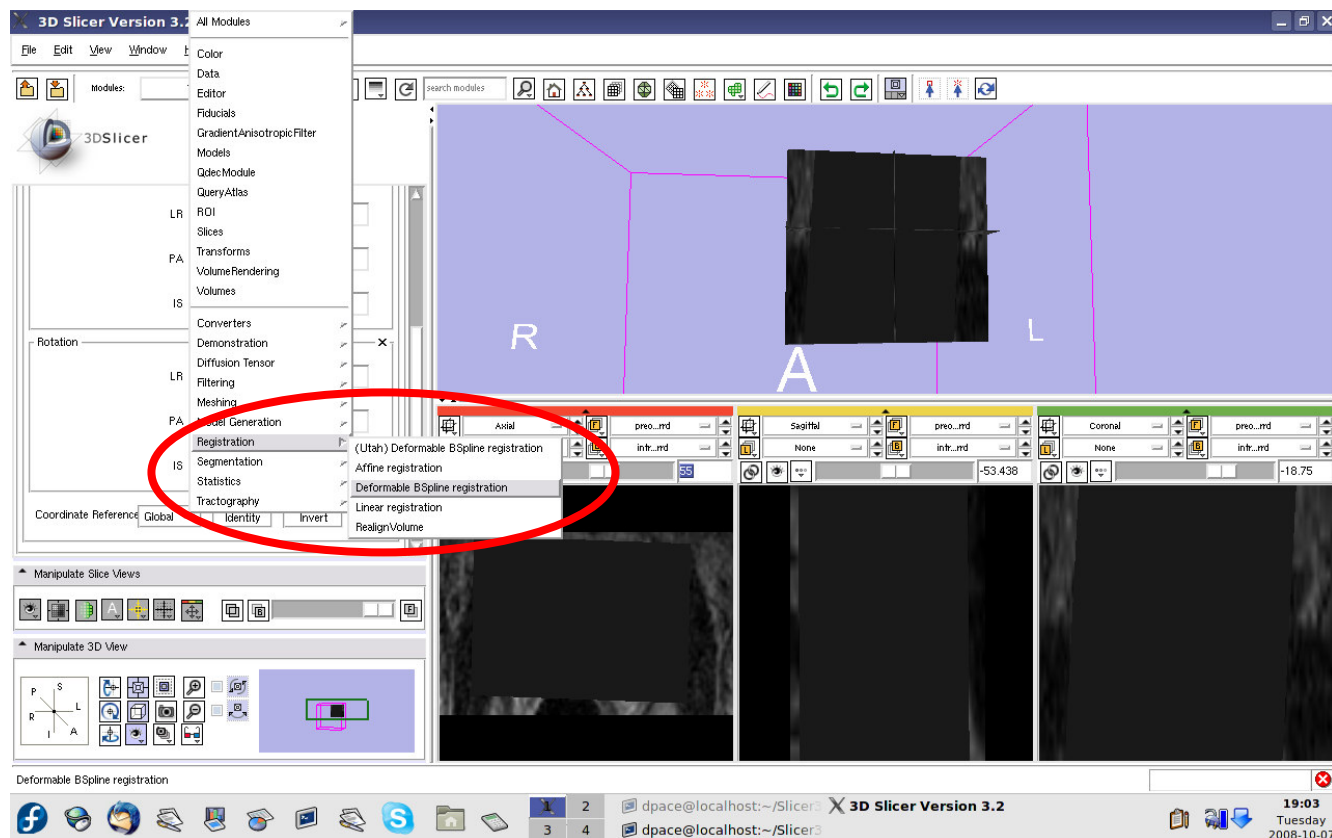
- Load the image volumes
 - Initial manual rigid transformation
 - Automatic affine registration
 - Automatic deformable B-spline registration
- Initializes transform*
- Initializes transform*

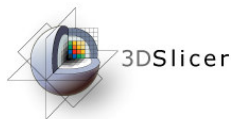


Deformable B-spline registration

**Perform the
deformable B-
spline
registration**

Open the
Deformable
Bspline
Registration
module

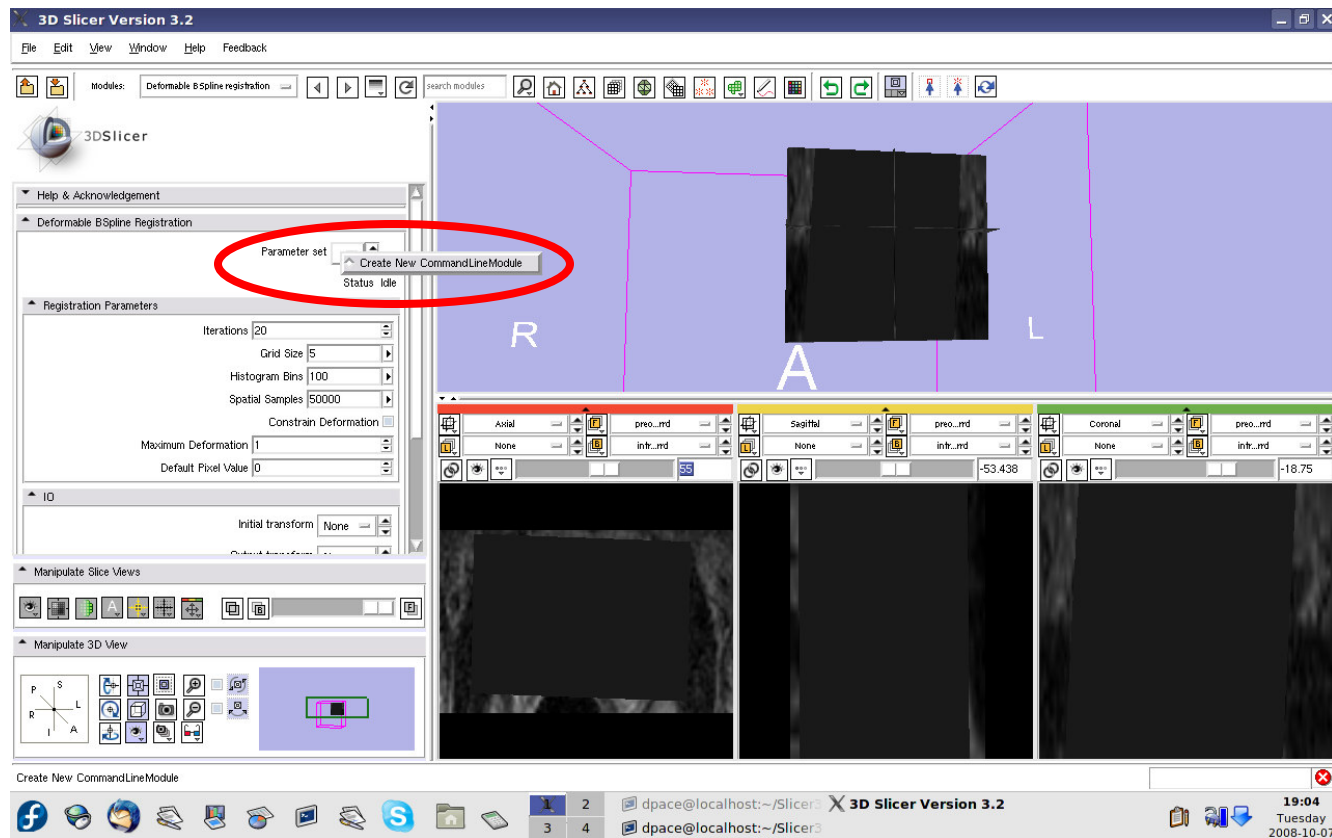


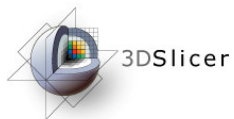


Deformable B-spline registration

Create a new deformable B-spline registration transform

You do not need to change any of the registration parameters

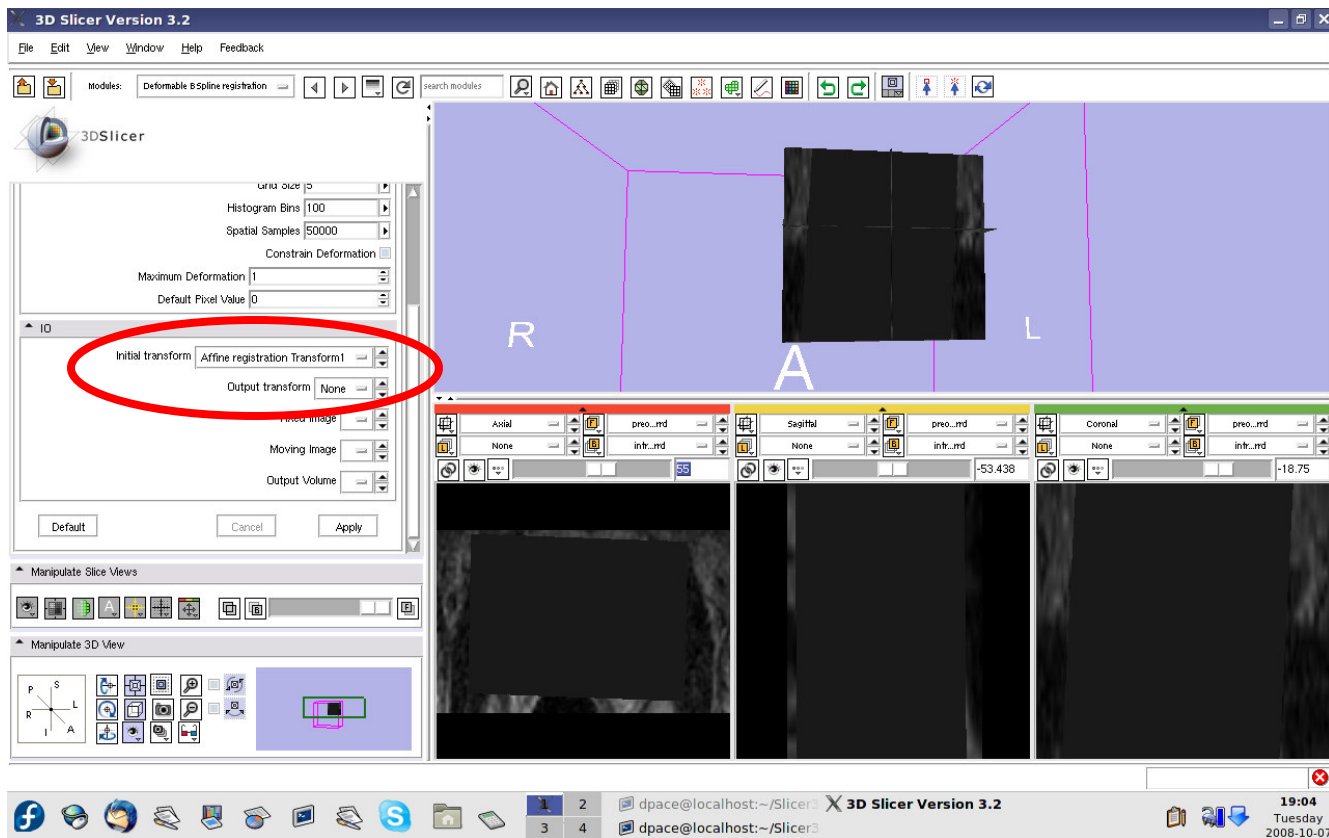




Deformable B-spline registration

Initial transform:
Affine
Registration Transform1

Output transform:
None



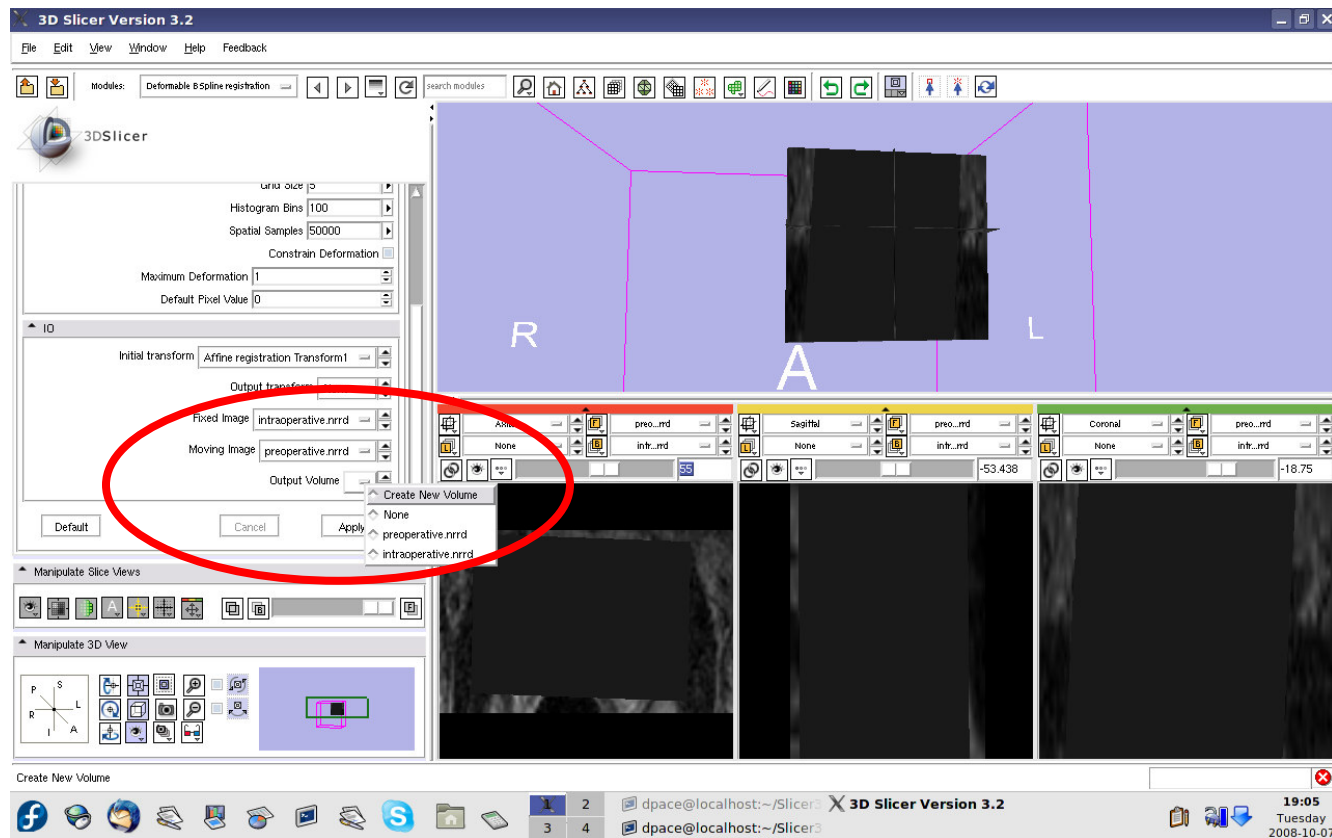


Deformable B-spline registration

Fixed image:
intra-operative

Moving image:
pre-operative

Output Volume:
Create new volume



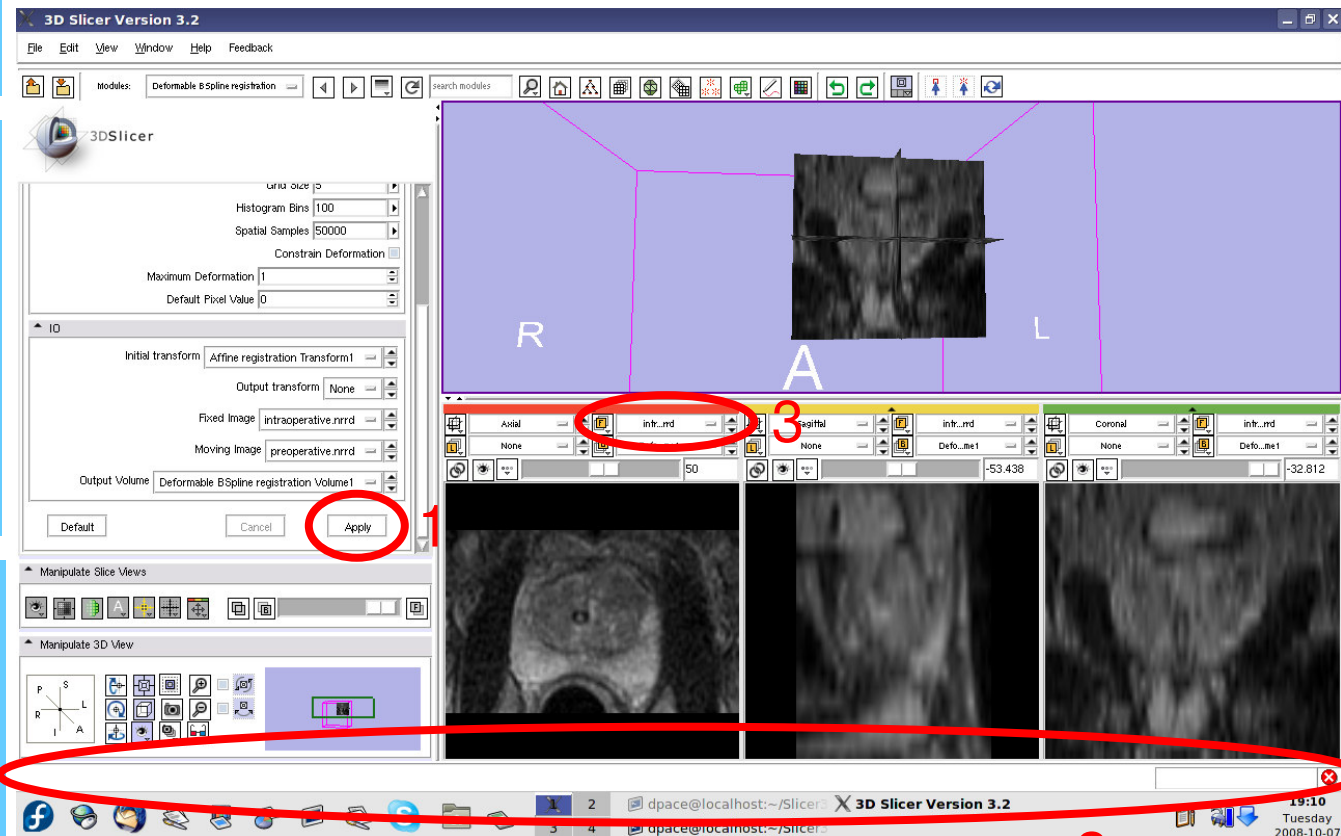


Deformable B-spline registration

Click “Apply”

View the progress bar and wait until it says “Completed”

Set the foreground to the intra-operative image

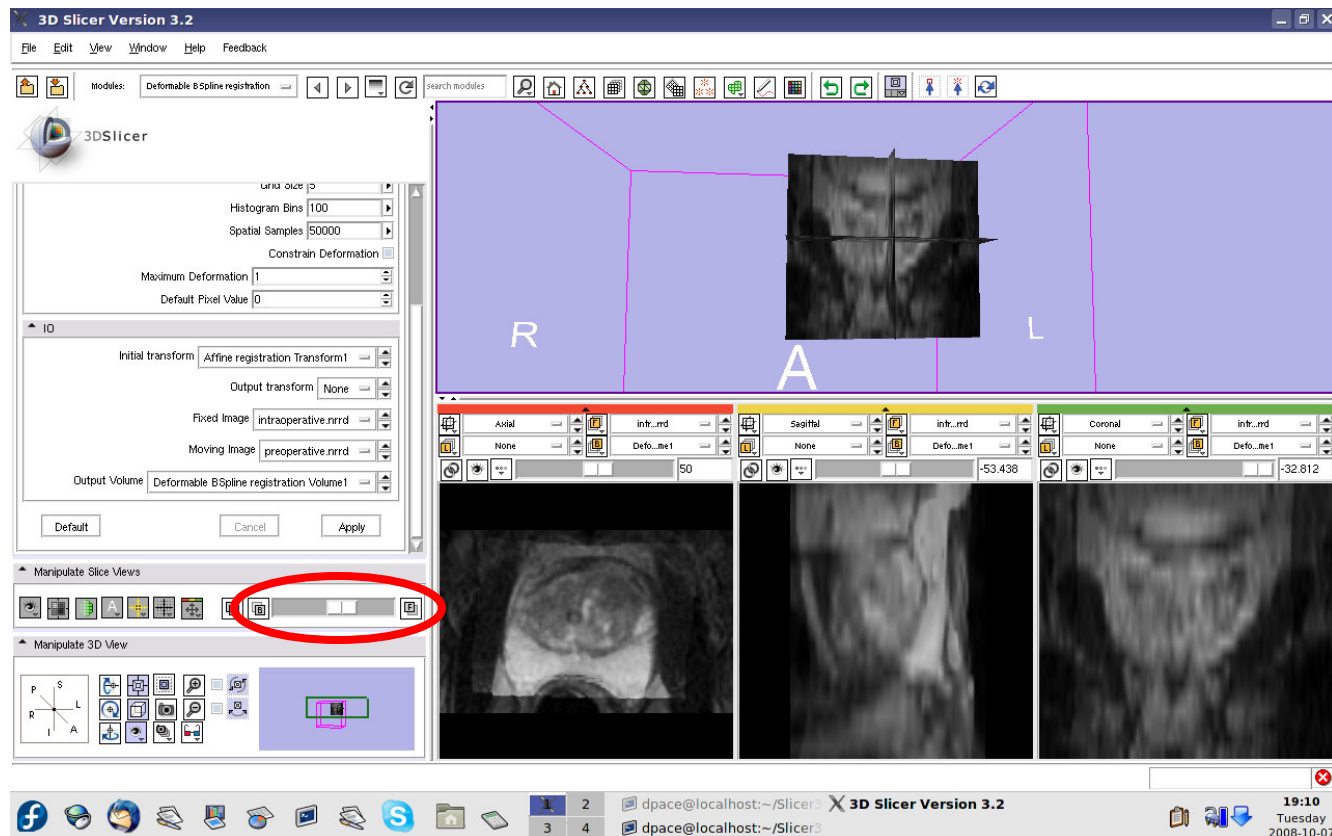




Deformable B-spline registration

Evaluate the deformable B-spline registration

Scale between the foreground and background to evaluate the alignment



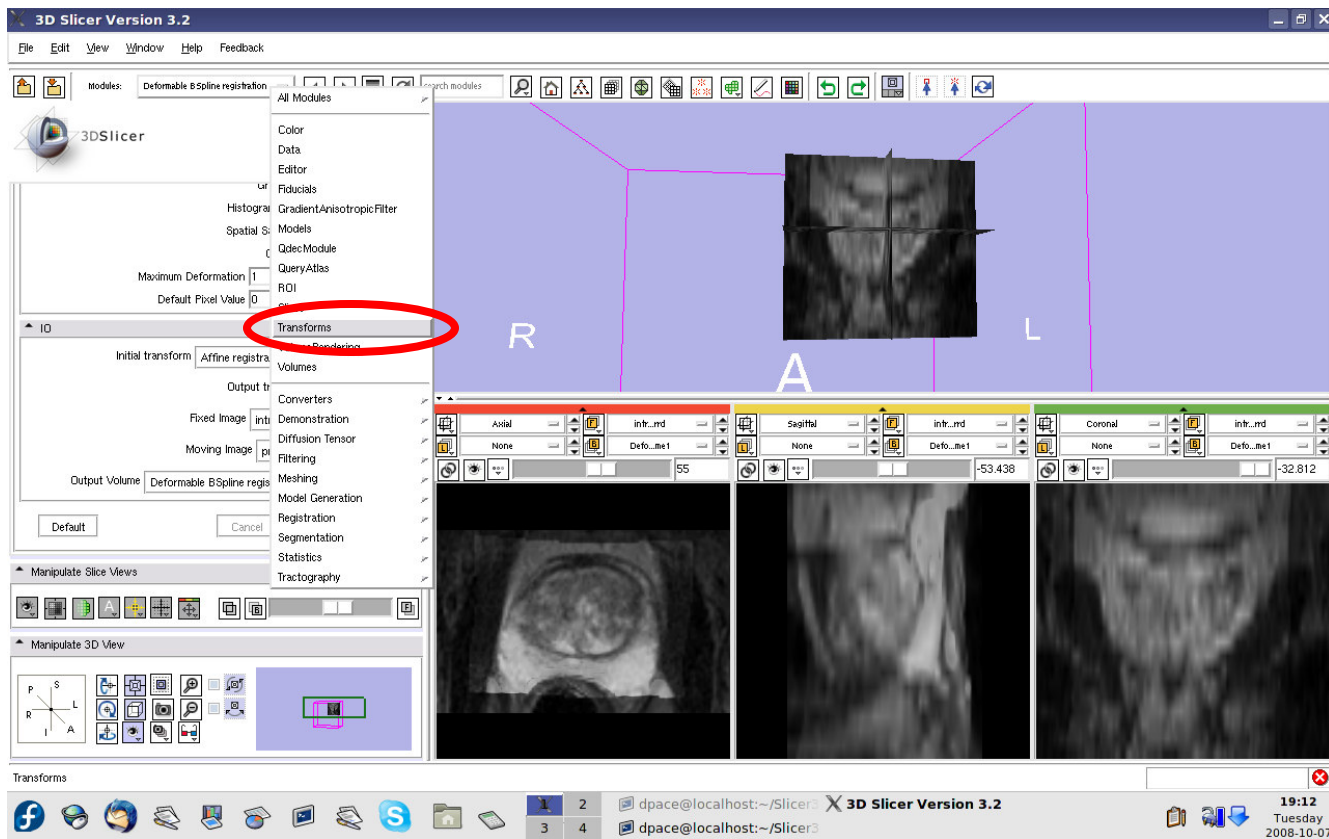


Deformable B-spline registration

Compare the deformable B-spline registration results to the affine results

The affine transform must be inverted back

Open the Transforms module



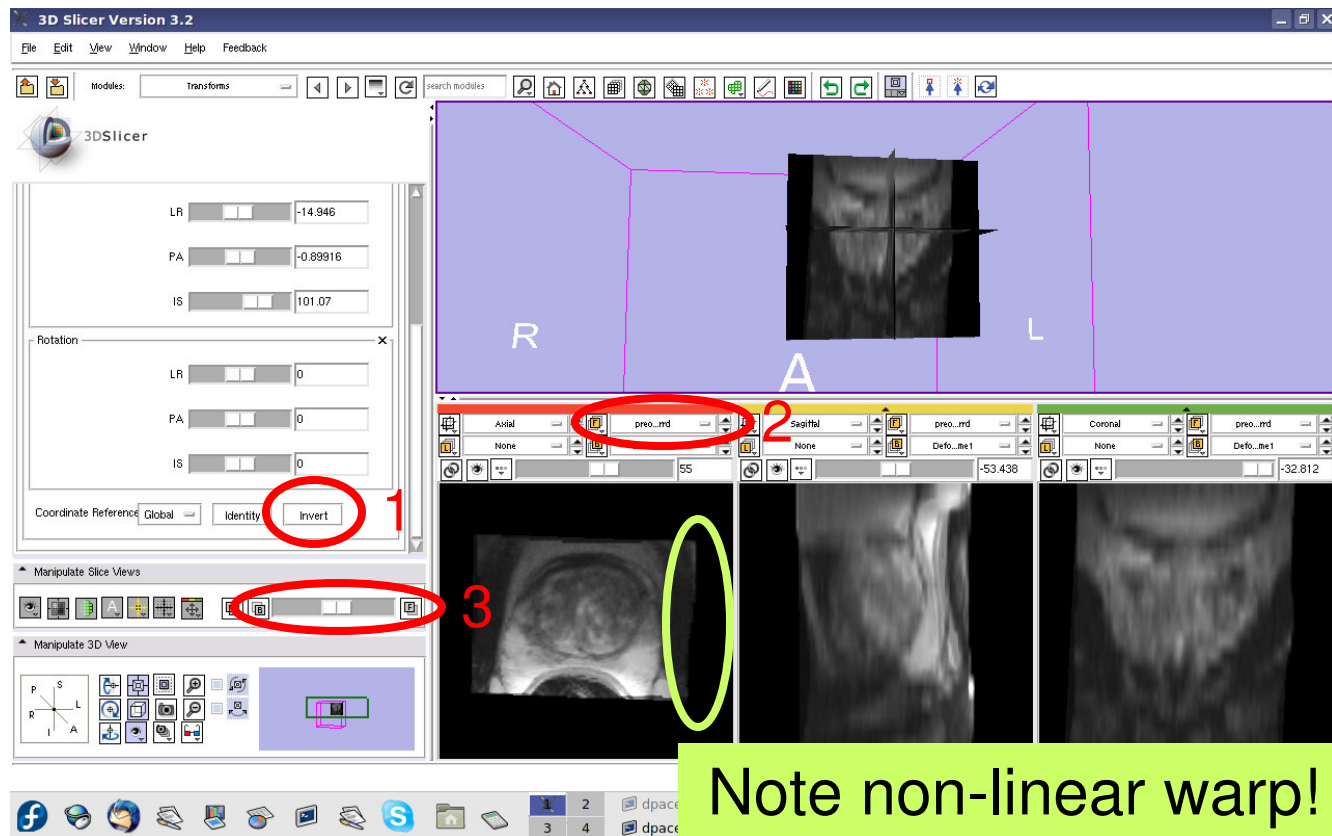


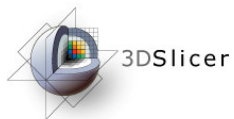
Deformable B-spline registration

Click on the “Invert” button

Set the foreground to the pre-operative image

Scale between the foreground and background to evaluate the alignment

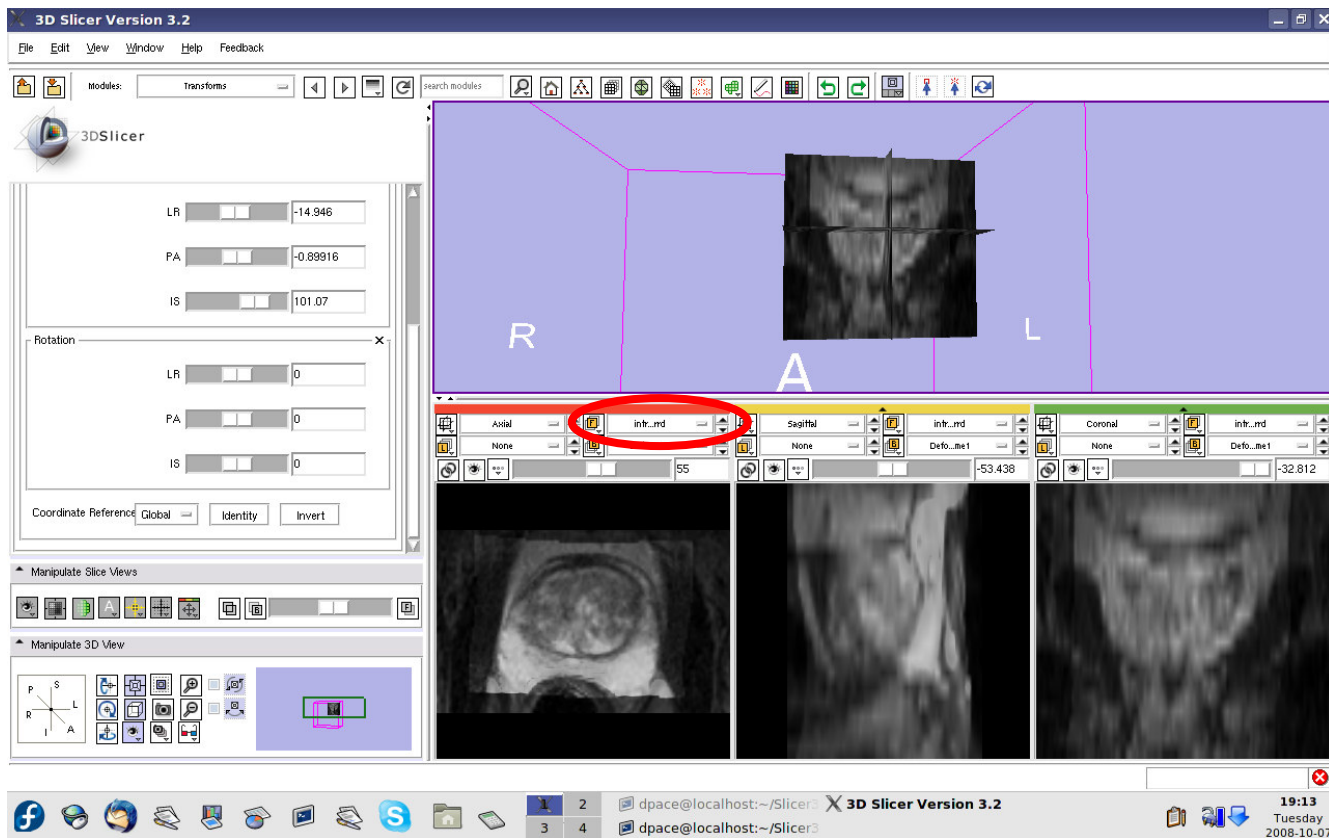




Deformable B-spline registration

Final results:

Set the foreground back to the intra-operative image





Conclusions

- The NA-MIC Kit can be used to perform the major computational steps in MR-guided prostate interventions
- Slicer3 provides an intuitive graphical user interface to interact with the data
- The NA-MIC Kit's open-source environment allows clinicians and researchers to share data and solutions to common problems



For more information

- For an example of using intraoperative MR for prostate interventions, see:

Haker, S.J. *et al.*, Magnetic resonance-guided prostate interventions. *Topics in Magnetic Resonance Imaging*, 16(5):355-368 (2005).

- For a review of non-rigid image registration, see:

Crum, W.R. *et al.*, Non-rigid image registration: theory and practice. *The British Journal of Radiology*, 77:S140-S153 (2004).



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