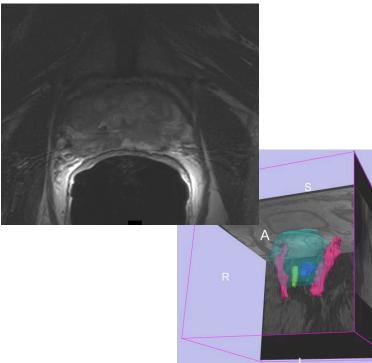


MR-guided prostate interventions with 3DSlicer and the NA-MIC Kit



Danielle Pace, B.CmpH. Sota Oguro, M.D. Steve Haker, Ph.D.

Surgical Planning Laboratory

Brigham and Women's Hospital

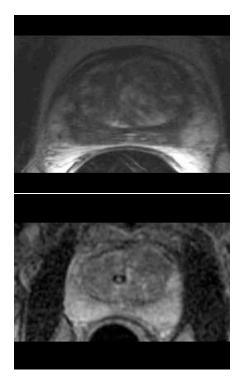
Harvard Medical School

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 intraoperative prostate MR images using deformable
 B-spline registration
- Incorporate models of the neurovascular bundle using image segmentation and model making
- Manually segment images
- Create 3D models from segmentations





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



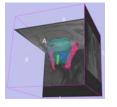
This tutorial requires the installation of the **Slicer3** software and the tutorial dataset. They are available at the following locations:

- 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

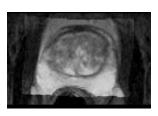
Disclaimer: It is the responsibility of the user of Slicer to comply with both the terms of the license and with the applicable laws, regulations, and rules.



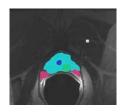
Overview



1. MR-guided prostate interventions: clinical background



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

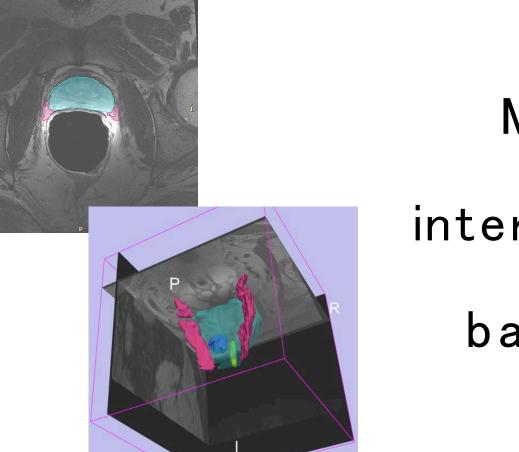


3. Manual segmentation of images



4. Creating 3D models from segmentations



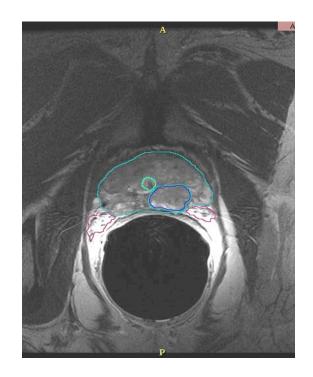


MR-guided prostate interventions: clinical background



Prostate cancer

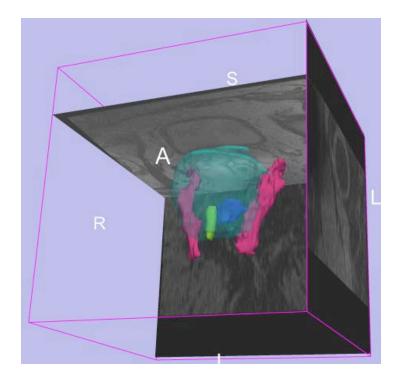
- Prostate cancer has the second-highest mortality rate of all cancers in American men: one in six men will be diagnosed, and it kills one in thirty-five (American Cancer Society)
- Diagnosis:
 - Prostate specific antigen (PSA) level
 - Digital rectal exam
 - Needle biopsy (Gleason score)
- (Some) Treatment 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)

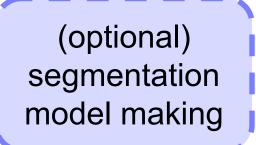




MR-guided prostate interventions

pre-operative

pre-operative MR imaging (high quality)



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 preoperative image and models of important structures



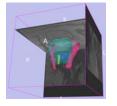
http://prostatemrimagedatabase.com

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

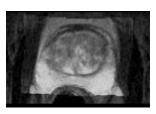
Welcome!								
Getting Started								
Get right to it view the image database! Peruse clinically relevant non-image data related to the cases in the database. Sopo and Purpose of this database. Frequently acked questions. Productly and view of this database. What's now in the database.								
Frequently asked questions. Vination powin the detabase. Glossary of terms used.	Prostate MR Image Database					WE REAL BWI		
For Clinicians	Patient/Exam List				MAT	C SOR	A.C.	
 Background and introduction to prostate MR imaging. Overview of the ongoing image Suided Thoracy Program at Brigham and Women's Hospital, including multi-media presentations. A selection of <u>Interesting cases</u> from the database. A balaggraphy for prostate MR imaging and image-puided therapy. 					THAGE	UIDED THEAS	es i	
For Scientists and Engineers		Patient Exam	Exam Description	Number Of Series	Exam Date	View Download		
Tochnical details on the image formatic used here. Code for reading the images and header information. Siloc, the recommended platform for viewing and proceessing image volumes. Other Code for processing images, such as registration code.		000001 00001	PROSTATE BIOPSY	2	Day 42	View Download		
		000001 00002	PROSTATE	5	Day 1	View Download		
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		000002 00002	PROSTATE	5	Day 1	View Download		
Other Relevent Links		000003 00001	BRACHYTHERAPY	1	Day 255	View Download		
		000003 00002	PROSTATE STAGING	5	Day 1	View Download		
A database of publications from our group. Affiliated laboratories and external collaborators.		000004 00001	PROSTATE BX	2	Day 36	View Download		
 External links related to prostate disease, imaging and therapy. 		000004 00002		9	Day 1	View Download		
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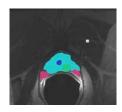
Overview



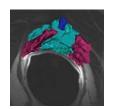
1. MR-guided prostate interventions: clinical background



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



3. Manual segmentation of images



4. Creating 3D models from segmentations



Registering pre-operative & intra-operative prostate MR images

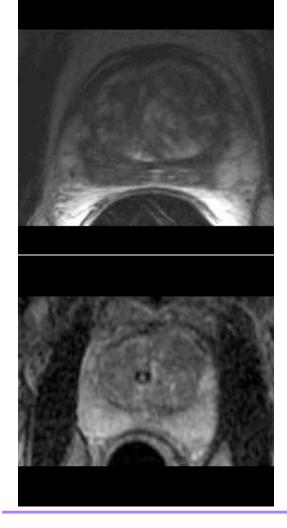




Image Registration

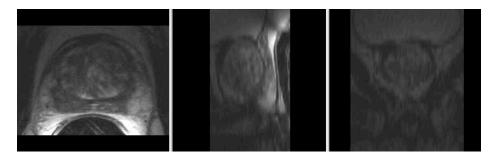
 Image registration aligns two images together with the goal of making the corresponding anatomy overlap

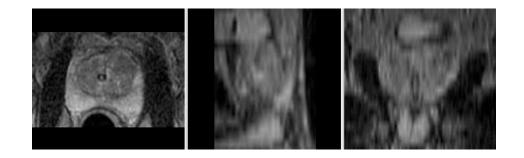
Pre-operative

- 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

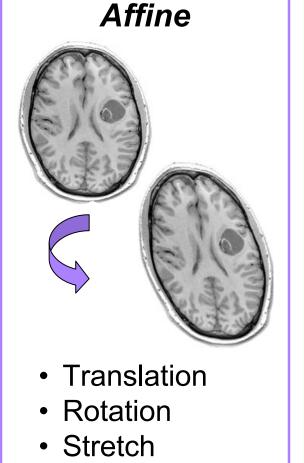




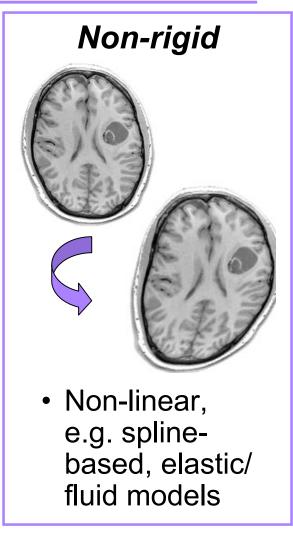


Three transformation models

Rigid Translation Rotation

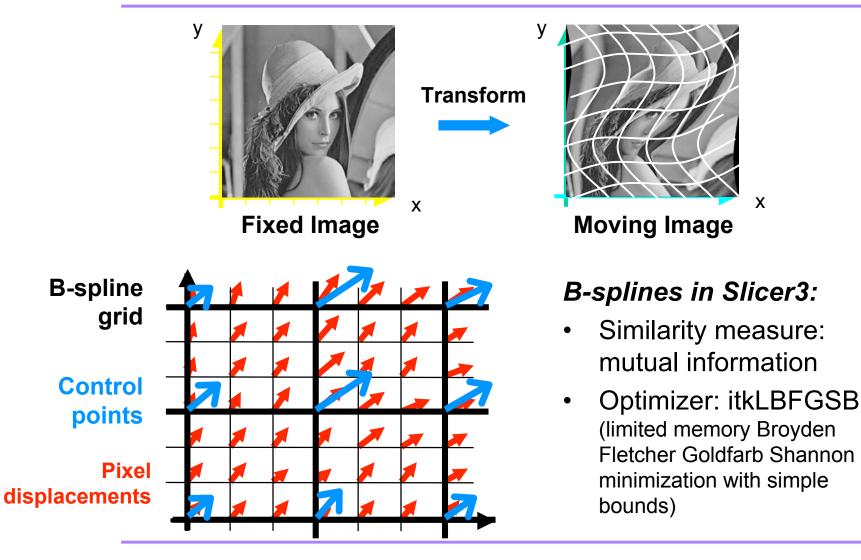


• Shear





Deformable B-spline registration

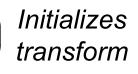




Registration Steps

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



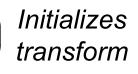




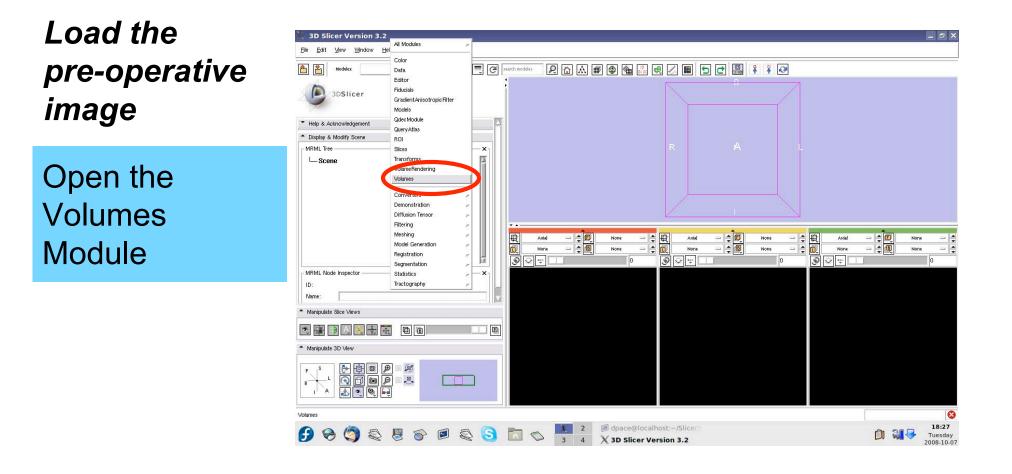
Registration Steps

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



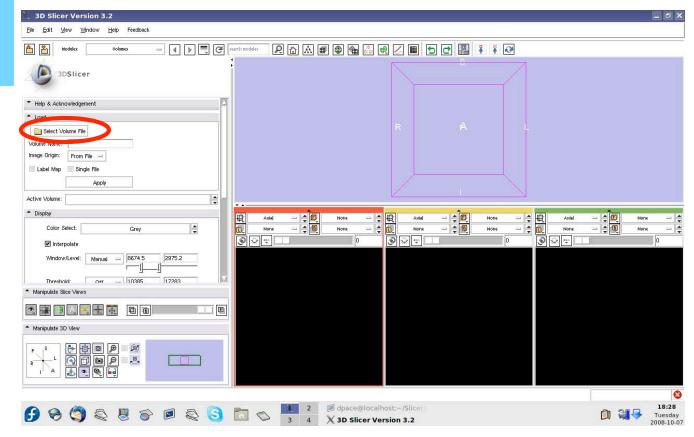








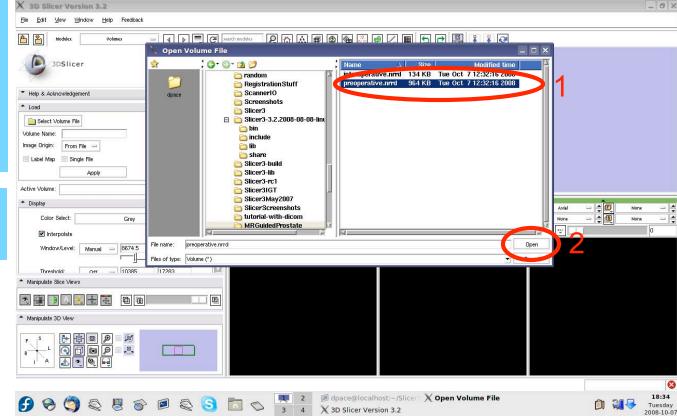
Click on "Select Volume File"



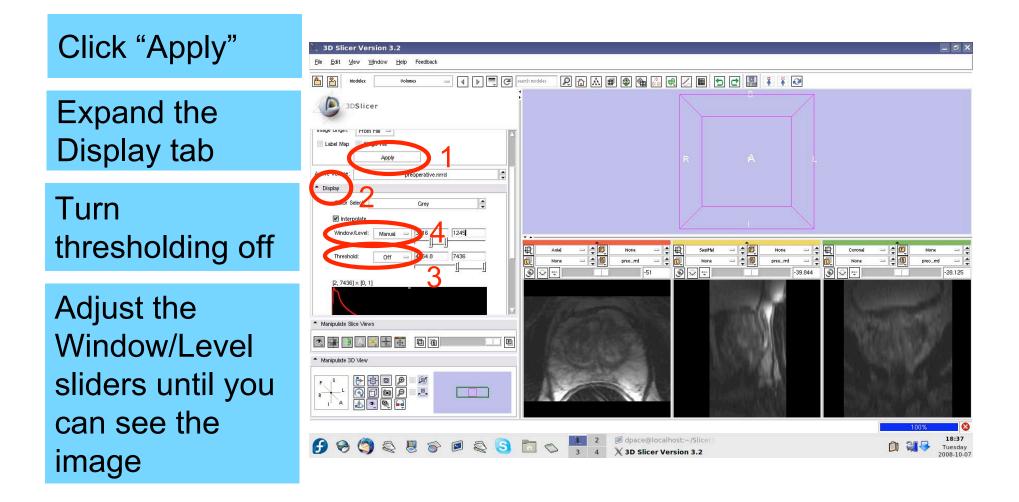


Select the pre-operative image: preoperative.nrrd

Click "Open"









Click on the slice control link button

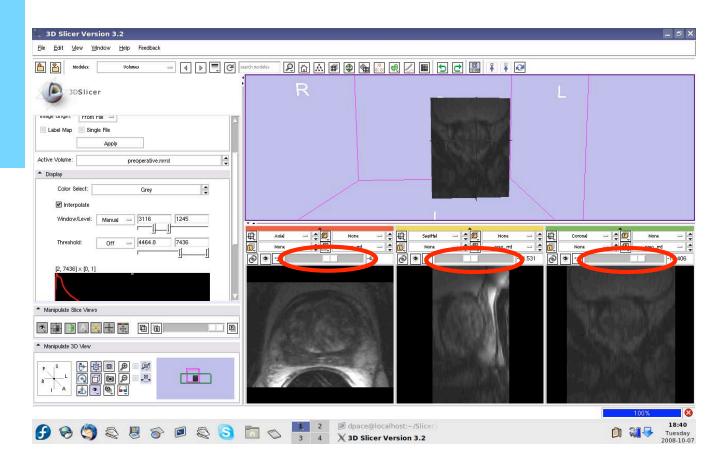
Toggle the slice visibility to see the slices in the 3D viewer

Center the 3D view on the scene and zoom in

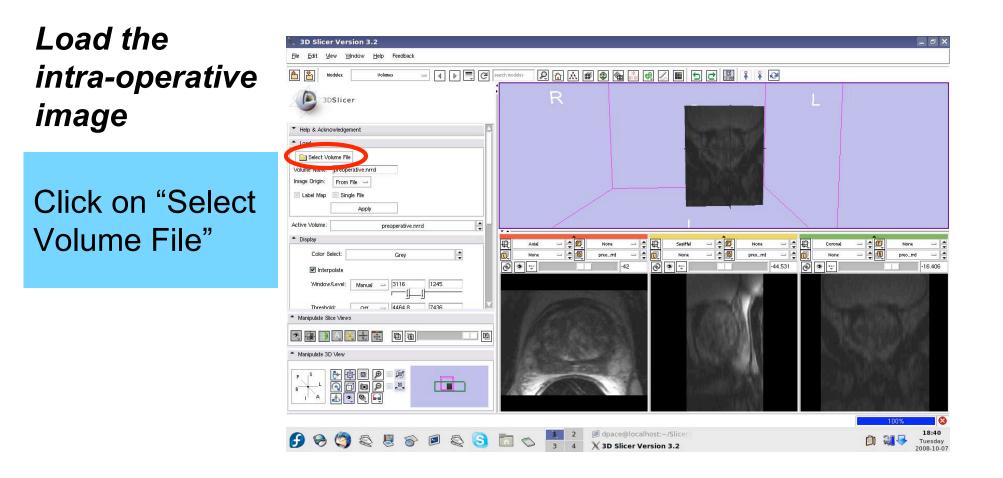
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Use the slice selector sliders to explore the dataset



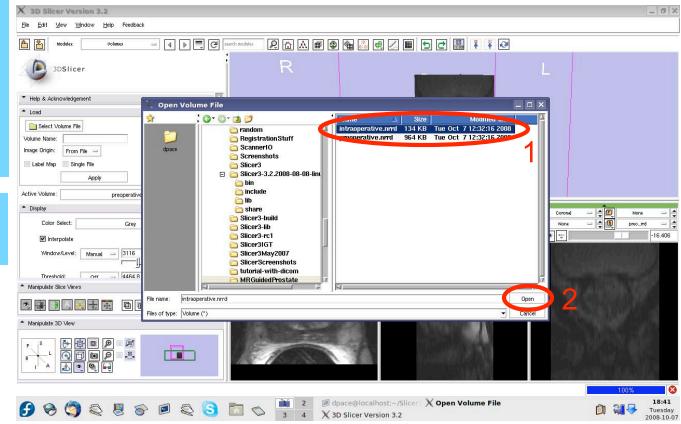






Select the intra-operative image: intraoperative.nrrd

Click "Open"



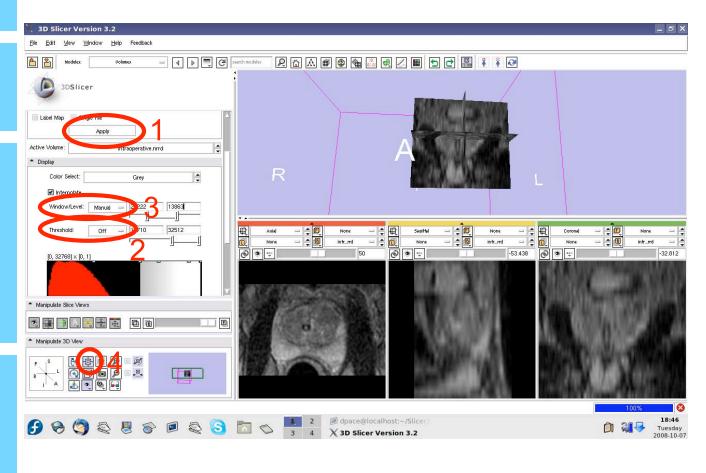


Click "Apply"

Turn thresholding off

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

Center the 3D view on the scene





Note that the images are not aligned

Set the foreground to the preoperative image

Scale between the foreground and background

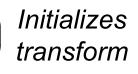
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Registration Steps

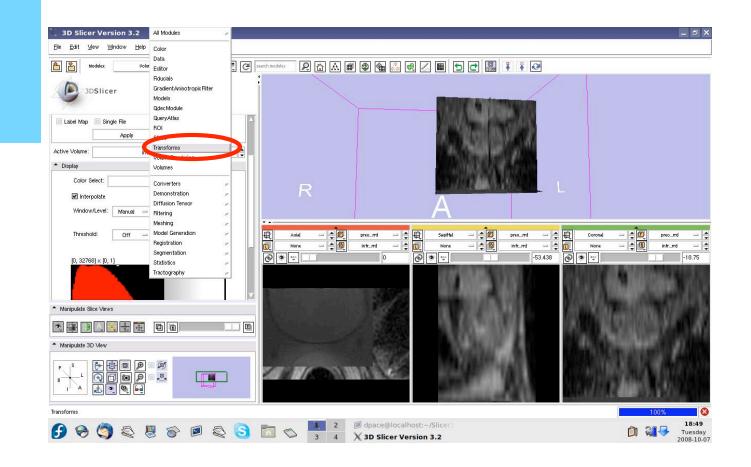
- Load the image volumes
- Initial manual rigid transformation
- Automatic affine registration
- Automatic deformable B-spline registration





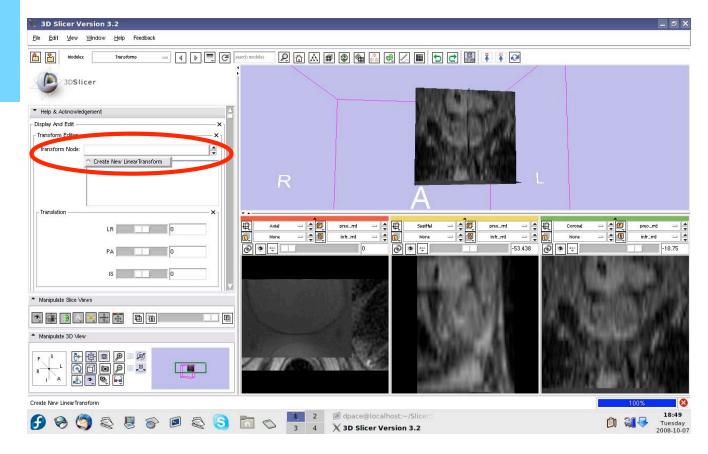


Open the Transforms module



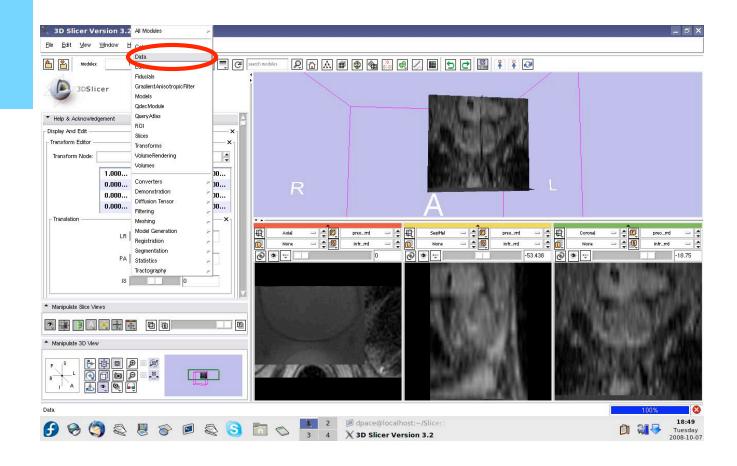


Create a new linear transform





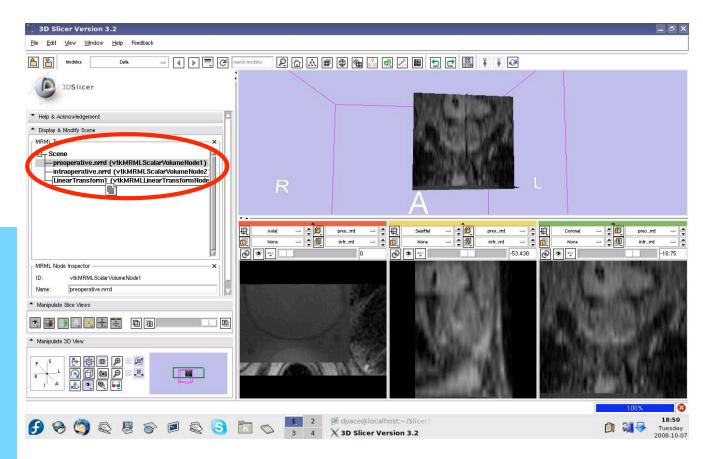
Open the Data module





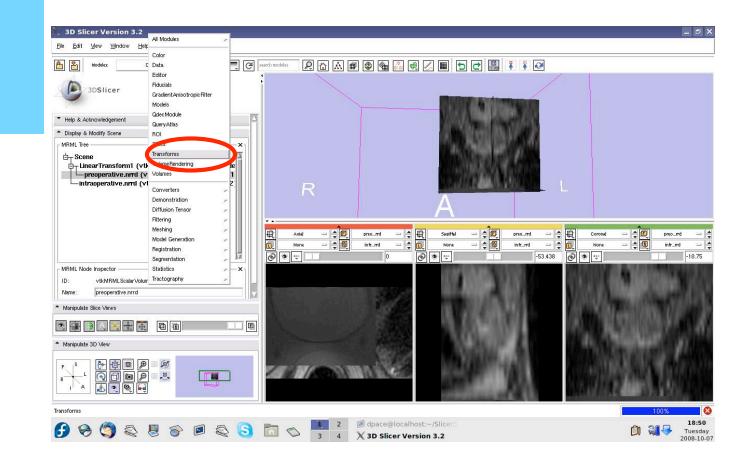
Apply the manual rigid transformation to the pre-operative image

Drag the pre-operative image under the Linear Transform1 node





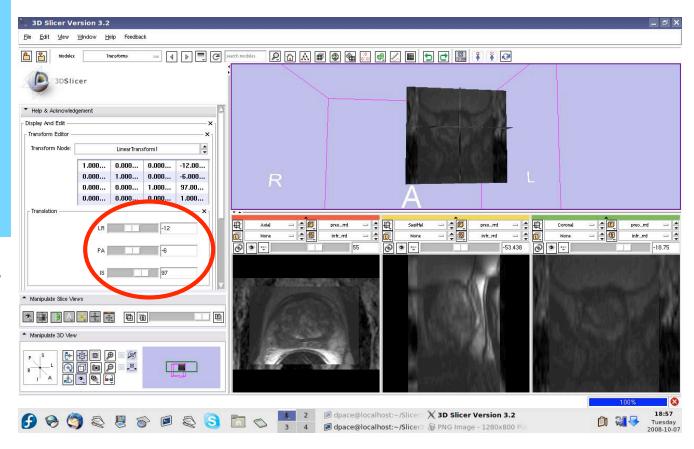
Open the Transforms module





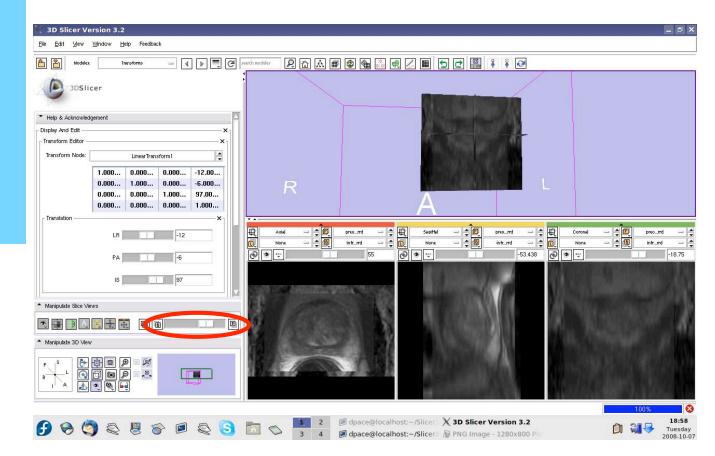
Manually adjust the translation and rotation parameters to align the two image volumes

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



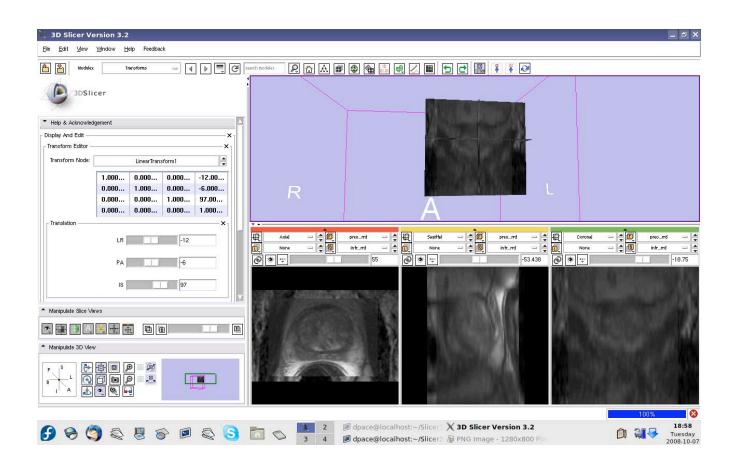


Scale between the foreground and background to evaluate the alignment



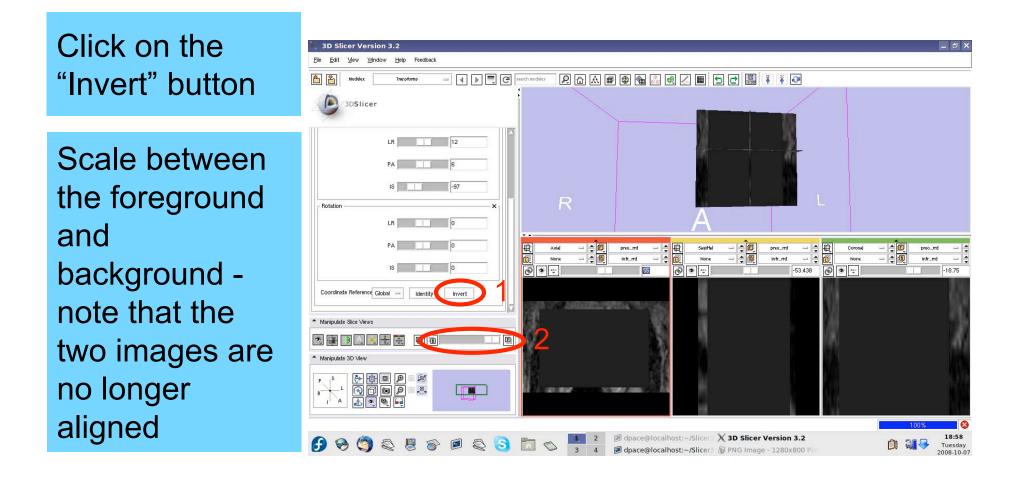


The initial transformation "pushes" the pre-operative image onto the intra-operative image, but Slicer's registration algorithm expects the inverse





Manual rigid transformation





Registration Steps

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

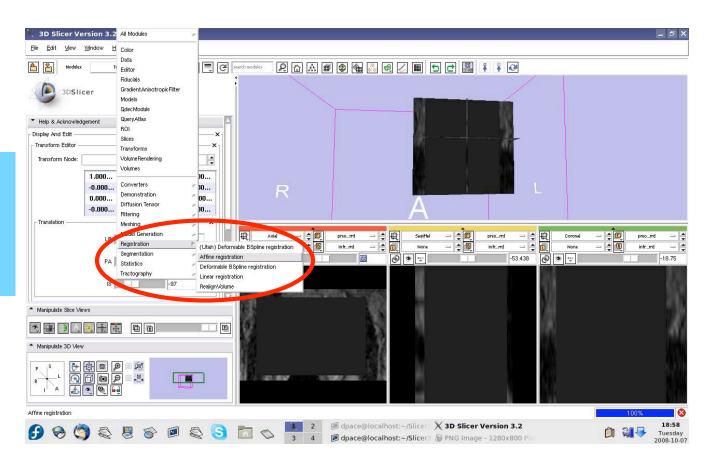


Initializes transform



Perform the affine registration

Open the Affine Registration module





Create a new affine registration transform

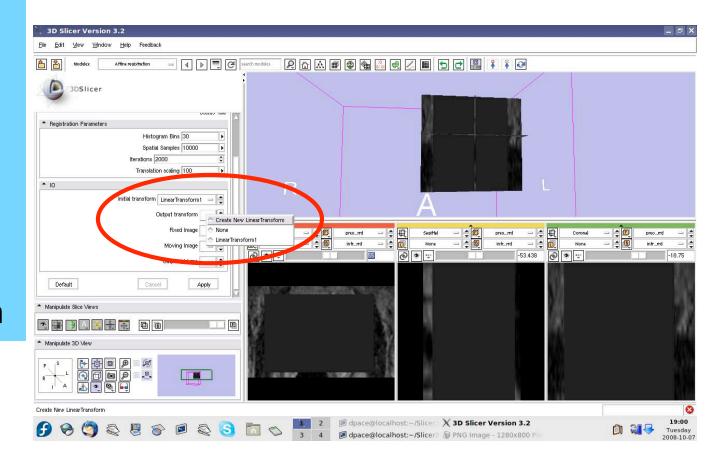
You do not need to change any of the registration parameters

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Initial transform: Linear Transform1

Output transform: Create new linear transform

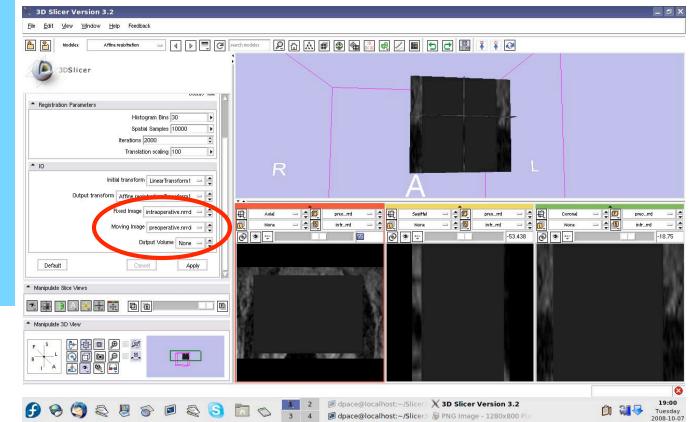




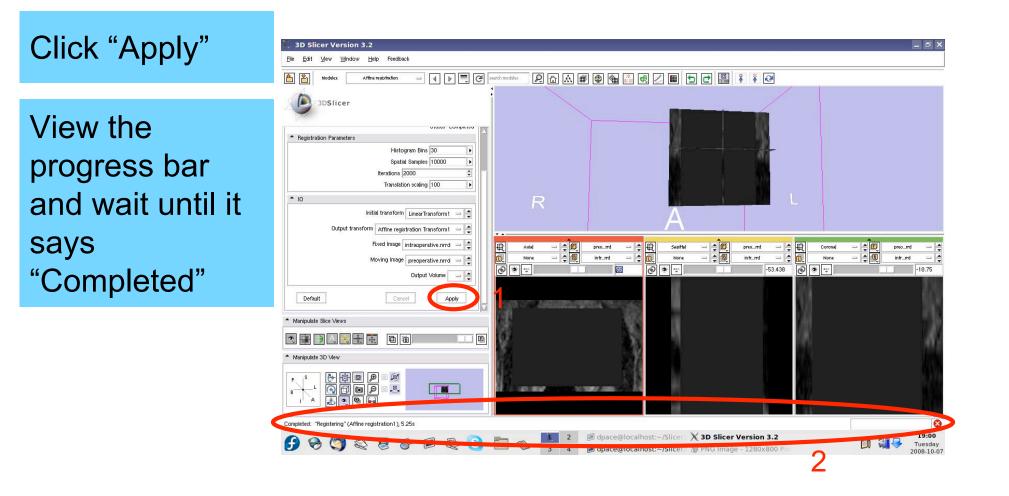
Fixed image: intra-operative Moving image:

pre-operative

Output Volume: None



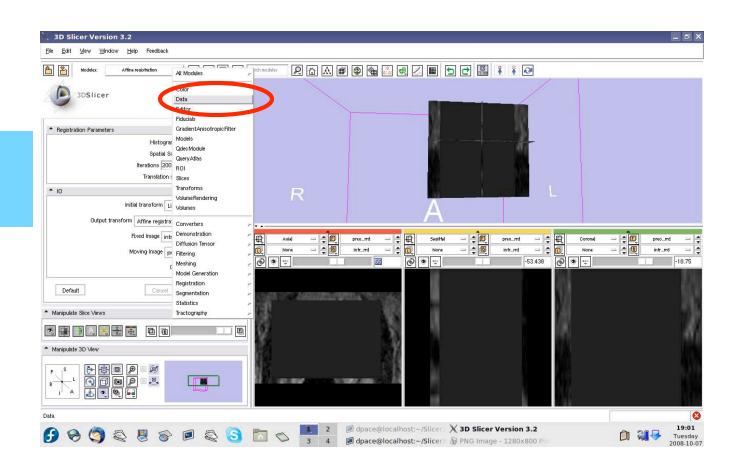






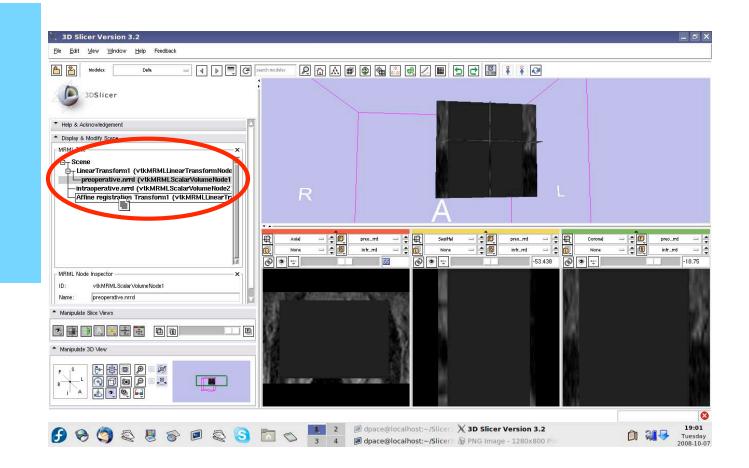
Evaluate the affine registration

Open the Data module





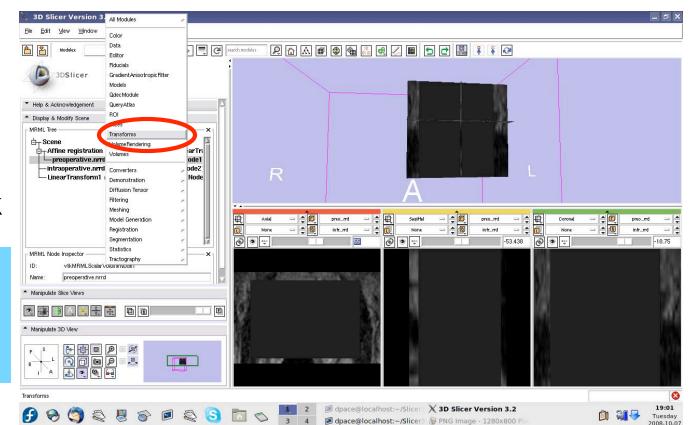
Drag the preoperative image under the Affine registration Transform1 node





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

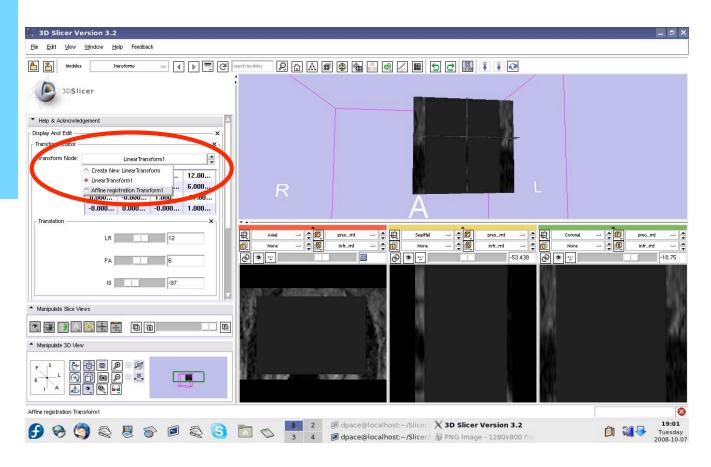
Open the Transforms module





Change the transform node to the affine registration transform

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





Click on the 3D Slicer Version 3.2 _ 0 × File Edit View Window Help Feedback "Invert" button **ê ě** - 🖣 🕨 📑 🤁 2 🟠 🛋 🚳 🍓 📖 🔍 🔳 🕤 🛃 🧍 🤾 🥵 Transforms 3DSlicer Scale between LR -14.946 PA -0.89916 the foreground IS 101.07 Rotation and LR 0 - - -PA 0 Sagittal None - preo...rrd Axial preo...rrd preo...md background to None intr...rrd intr...rrd - intr...rd None 🔊 🐨 🐨 15 0 55 @ * ~ -18.75 -53.438 Coordinate Reference Global 😑 evaluate the Identity Manipulate Slice Views alignment Manipulate 3D View - Ø dpace@localhost:~/Slicer® X 3D Slicer Version 3.2 19:02 🗲 🕱 🧐 🤤 🖉 🔗 🖻 😂 🔂 📩 👟 🏪 01 🔍 😽 Tuesday Jace@localhost:~/Slicer 2008-10-07



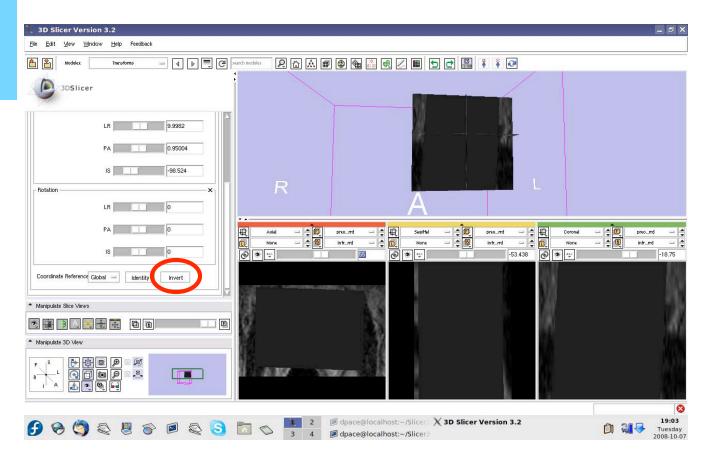
Now that we've evaluated the affine transform, it must be inverted before it can be used to initialize the deformable **B-spline** registration





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



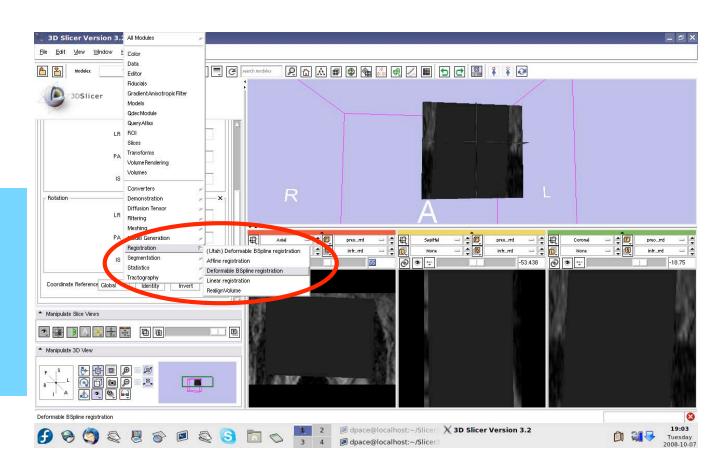
• Automatic deformable B-spline registration

Initializes transform



Perform the deformable Bspline registration

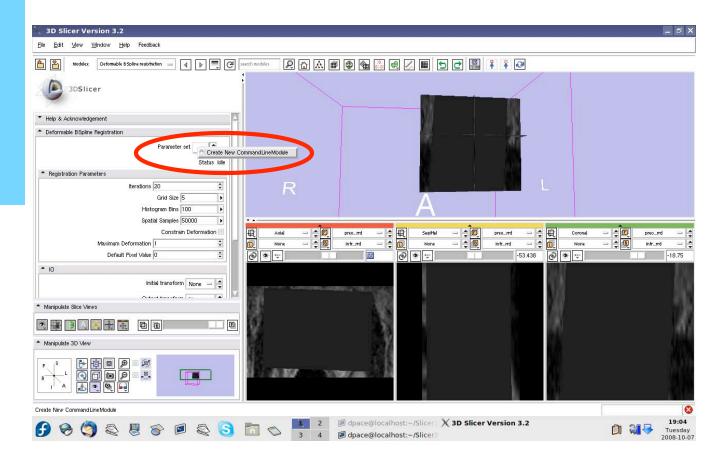
Open the Deformable **B**spline Registration module





Create a new deformable **B-spline** registration transform

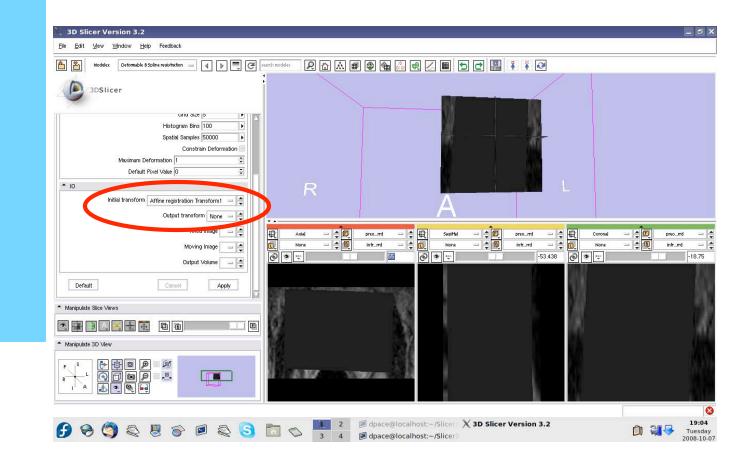
You do not need to change any of the registration parameters





Initial transform: Affine Registration Transform1

Output transform: None

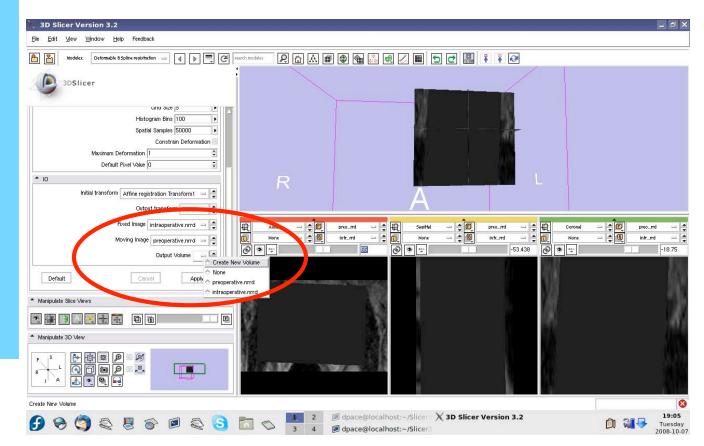




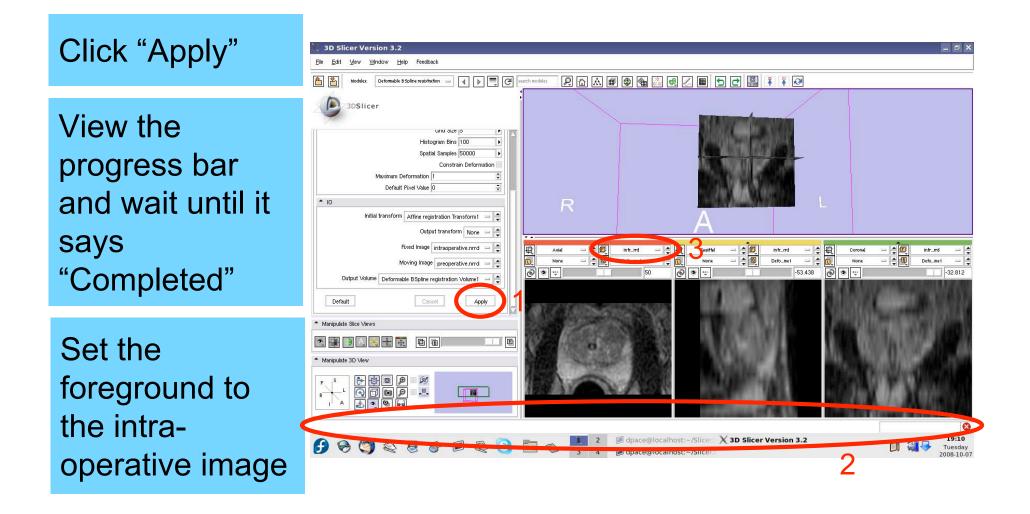
Fixed image: intra-operative

Moving image: pre-operative

Output Volume: Create new volume



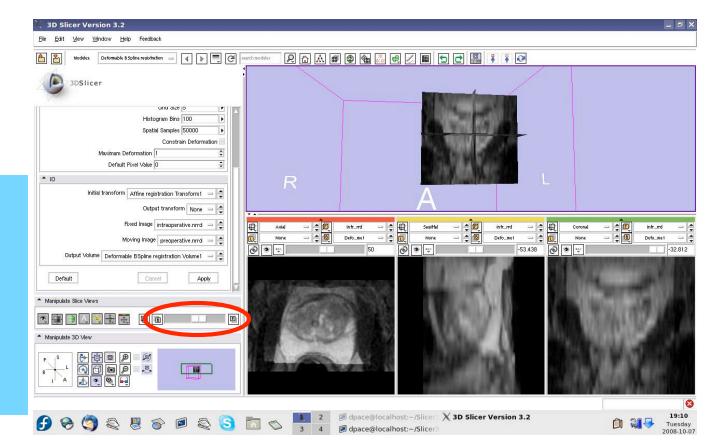






Evaluate the deformable Bspline registration

Scale between the foreground and background to evaluate the alignment

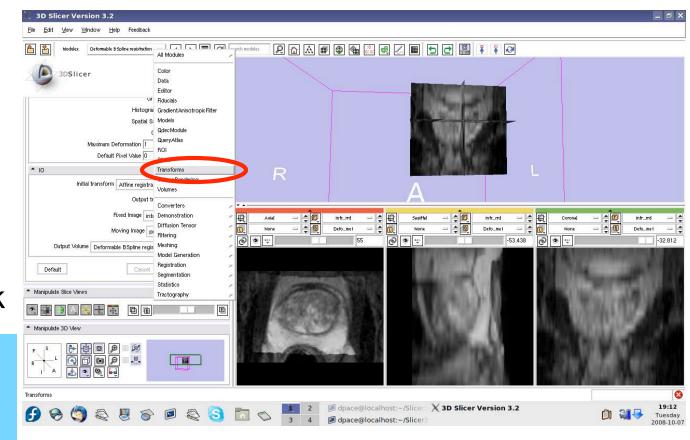




Compare the deformable Bspline registration results to the affine results

The affine transform must be inverted back

Open the **Transforms** module

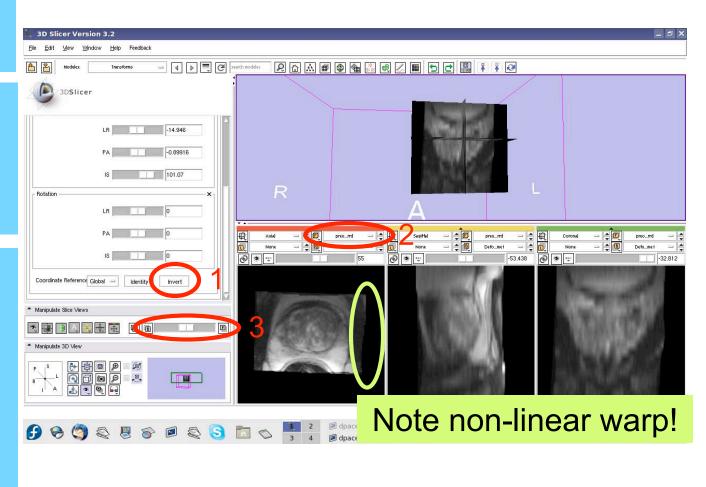




Click on the "Invert" button

Set the foreground to the preoperative image

Scale between the foreground and background to evaluate the alignment





Set the

image

Deformable B-spline registration

Final results:

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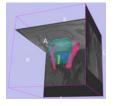
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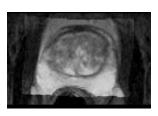
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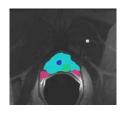
Overview



1. MR-guided prostate interventions: clinical background



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



3. Manual segmentation of images

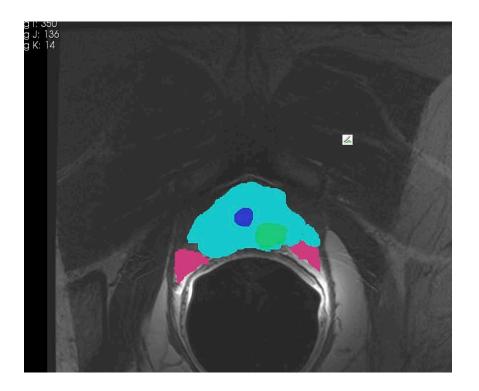


4. Creating 3D models from segmentations



Manual

segmentation is the process of delineating the anatomical structures within an image

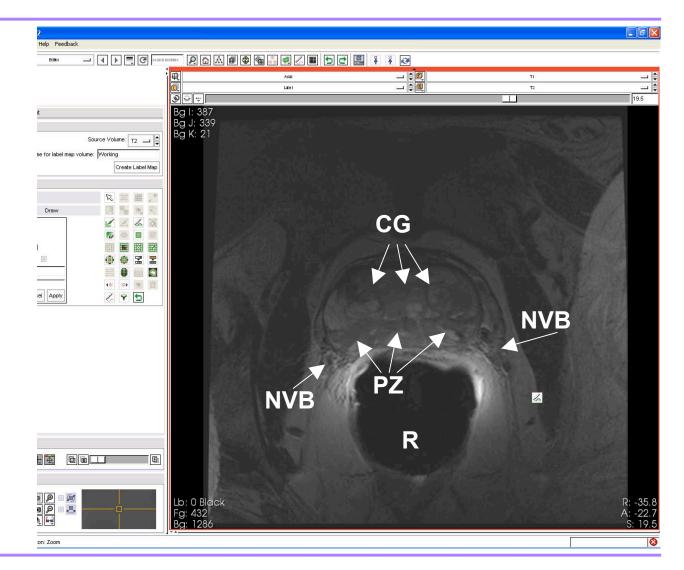


Manual Segmentation - Prostate

Prostate MR dataset

T2-weighted axial image at 3.0 Tesla

Central gland, peripheral zone, neurovascular bundles and rectum shown

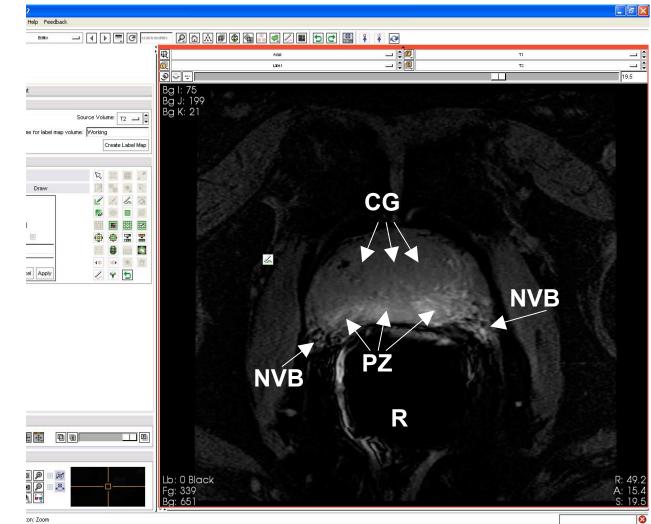


Manual Segmentation - Prostate

Prostate MR dataset

T1-weighted axial image at 3.0 Tesla

The T1 image can be used to complement T2 imaging visualization





Manual Segmentation - Load

Load the data

Sample segmentation data were previously saved in a scene file

Select "Load Scene" from the File menu

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3DSlicer

Manual Segmentation - Load

Select T2.mrml from the file selection menu and click "Open"

This scene contains T2 and T1 MR, plus an example label map

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Manual Segmentation - Layout

Select layout

Select the "Red slice only layout"

This will display axial MR slices for the segmentation

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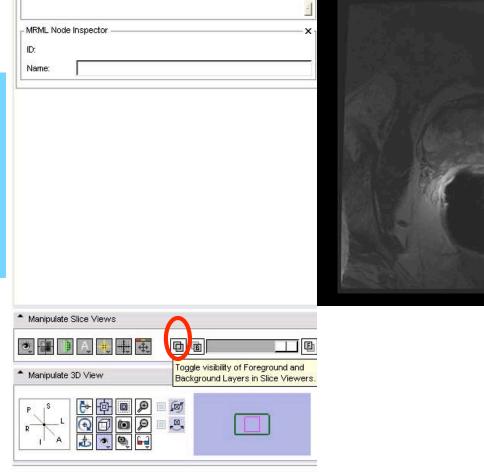


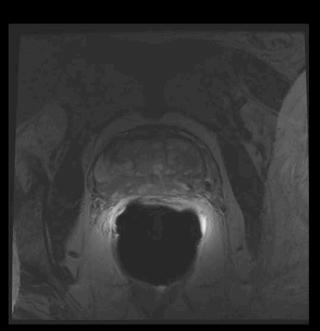
Manual Segmentation – Visibility

Toggle visibility

Toggle visibility to foreground so that the T2weighted image appears

The toggle allows for easy visualization of both the T1 and T2 images







Manual Segmentation – Visibility

Fit visible

The fit visible button zooms the image to fit the window

This presents the maximum image size to aid in visualization

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Manual Segmentation - Editor

Open the Editor module

The Editor module contains Slicer's drawing tools

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Manual Segmentation – Source

Select the source volume

This is the volume you will be drawing on

Select the T2 volume for this demonstration

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Manual Segmentation - Label Map

Enter a label map name

The label map will contain the segmentation results

Enter "Label" as the label map name

Press "Create Label Map"

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Manual Segmentation - Draw

Select the draw tool

Click on the pencil icon

The draw tool is used to contour regions of interest

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Manual Segmentation - Color

Select color

Click on the color box for the pop-up color selector

Use a different color for each anatomical region

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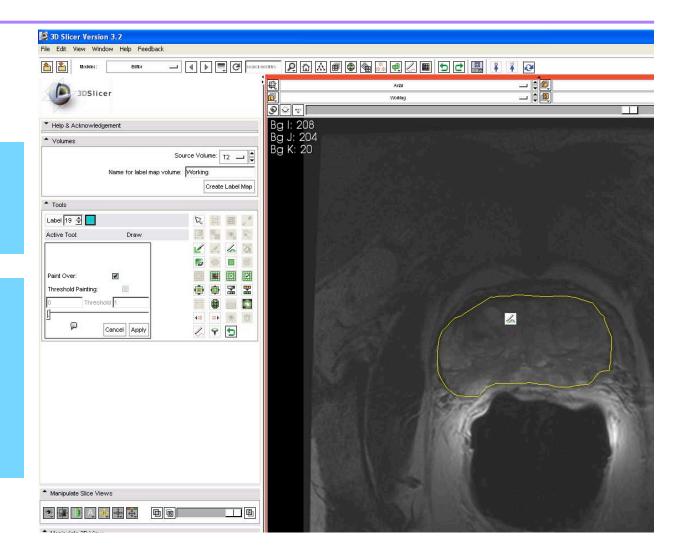


Manual Segmentation - Contour

Draw a closed contour

Contour the prostate

Press the 'a' key to fill in the region when complete

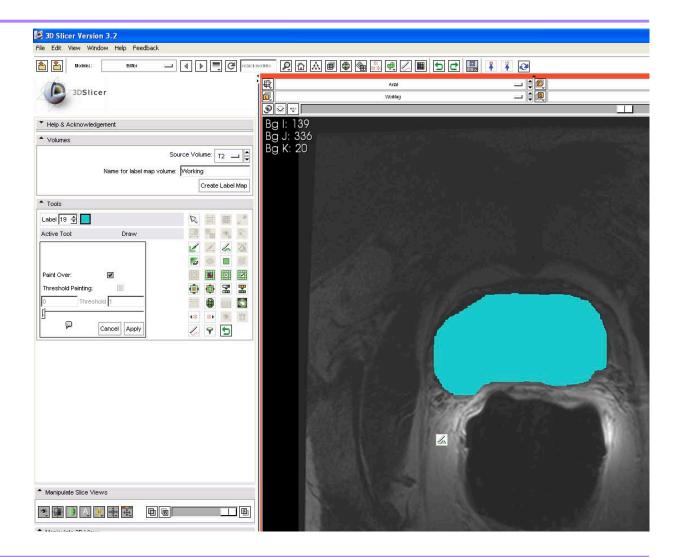




Manual Segmentation - Contour

The contour is filled in when 'a' is pressed

Here the boundary of the prostate gland has been contoured



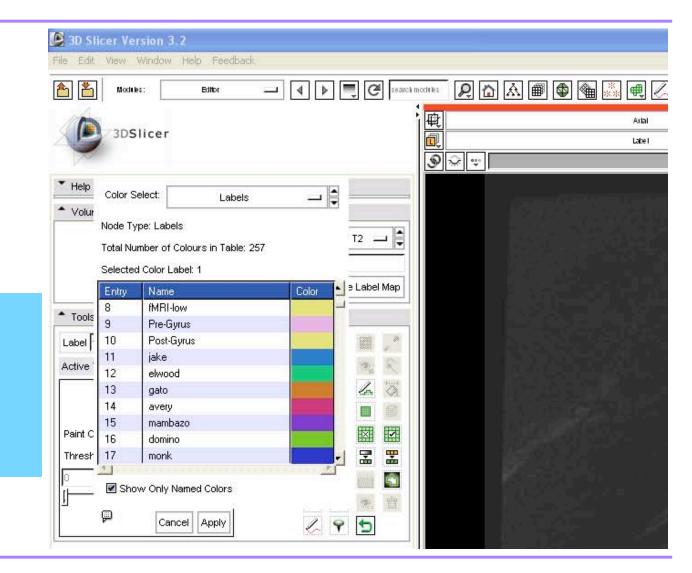


Manual Segmentation - Color

Select color

Change to a different color for another structure

Click on the color box for the pop-up color selector



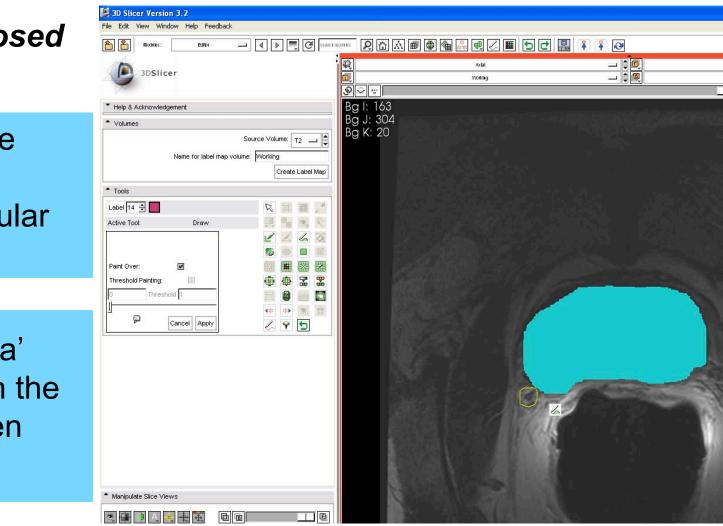


Manual Segmentation - Contour

Draw a closed contour

Contour the right neurovascular bundle

Press the 'a' key to fill in the region when complete

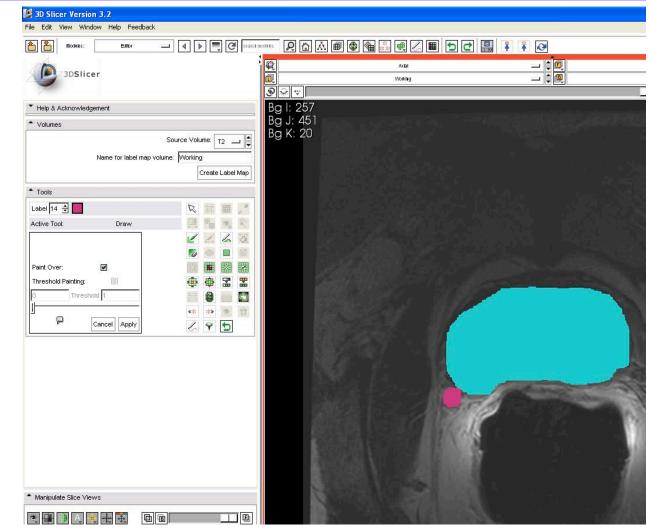




Manual Segmentation - Contour

The contour is filled in when 'a' is pressed

Here the right neurovascular bundle has been contoured



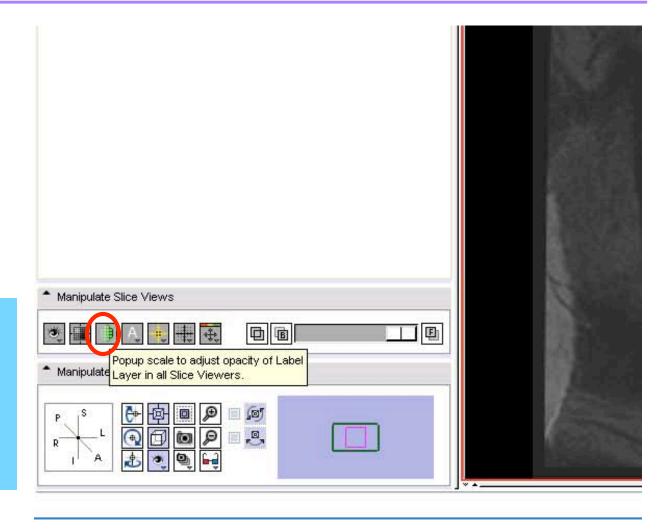


Manual Segmentation - Opacity

Set label opacity

This allows you to see beneath the contoured regions

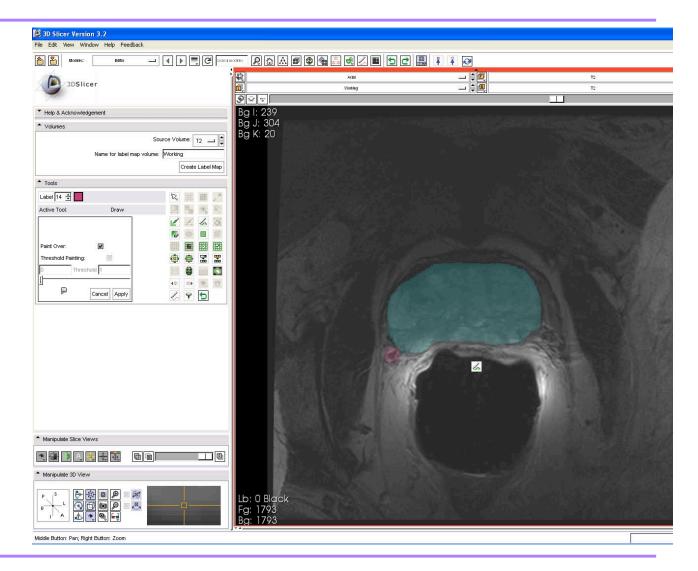
Select a value for the opacity using the popup slider





Manual Segmentation - Opacity

Now you can visualize the MR image and the selected regions at the same time





Manual Segmentation - Color

Select color

Change to a different color for another structure

Click on the color box for the pop-up color selector

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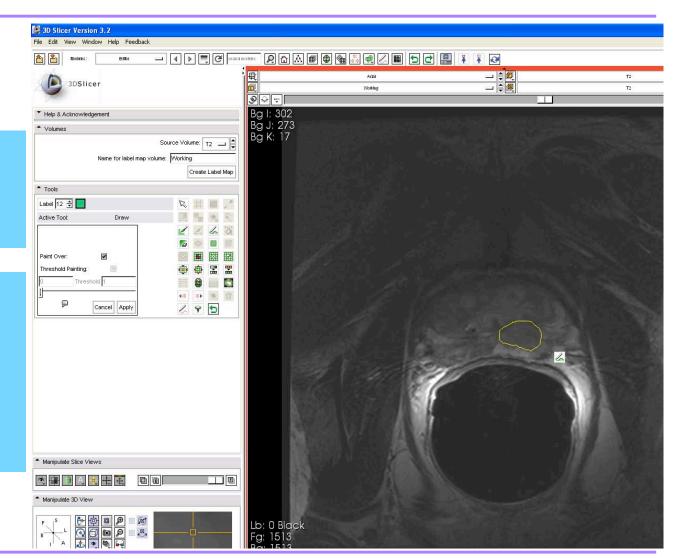


Manual Segmentation - Contour

Draw a closed contour

Contour the tumour

Press the 'a' key to fill in the region when complete

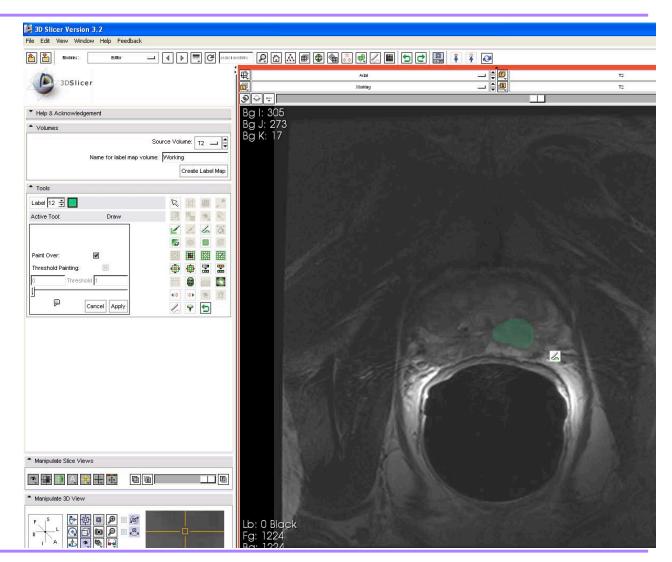




Manual Segmentation - Contour

The contour is filled in when 'a' is pressed

Here a suspected tumor has been contoured

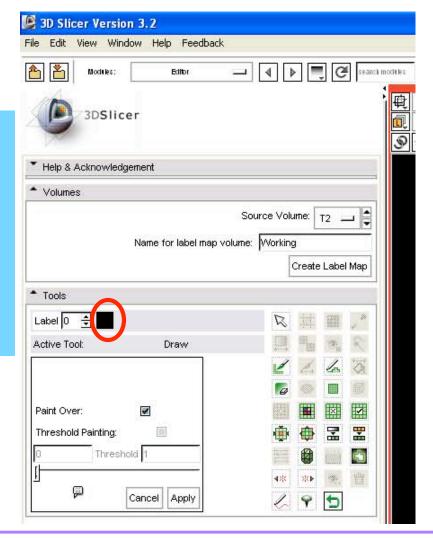




Manual Segmentation - Erase

To erase, draw with black

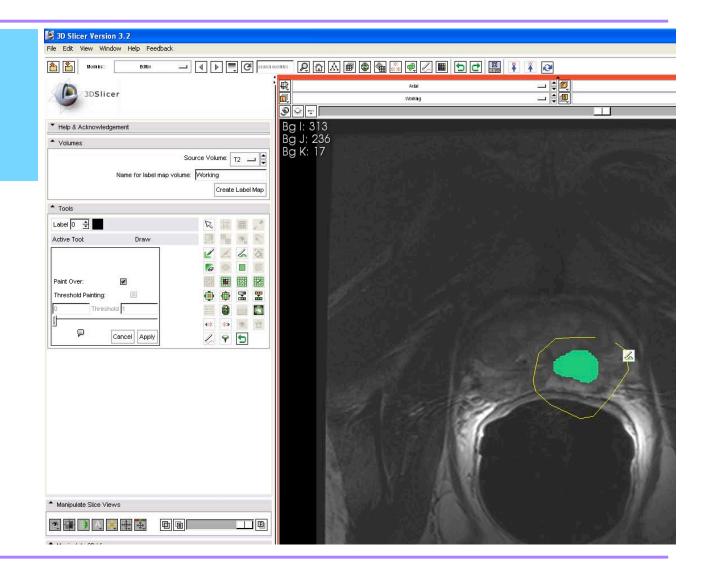
Click on the color box for pop-up color selector and choose black (label zero)





Manual Segmentation - Erase

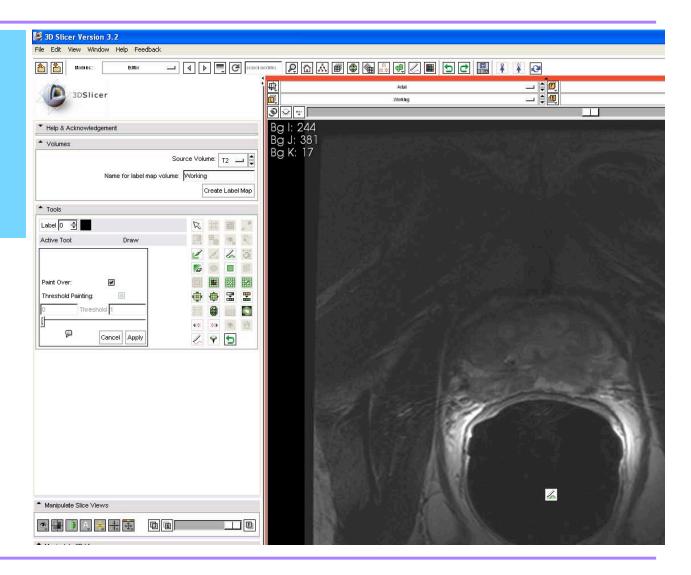
Contour the region to be erased





Manual Segmentation - Erase

Press the 'a' key to erase the region when complete

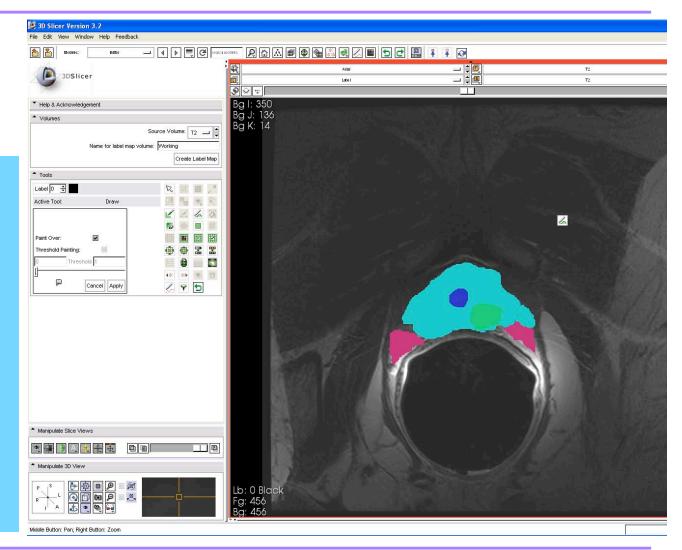




Manual Segmentation - Result

Segment all slices in the volume

For each slice in the volume segment the prostate, both neurovascular bundles and the tumour: use a consistent color scheme.





Manual Segmentation - Save

Save the segmentation

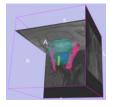
Select "Save" from the File menu

Save the labels and current settings in a scene file

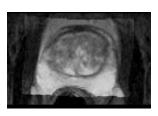
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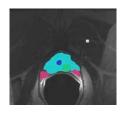
Overview



1. MR-guided prostate interventions: clinical background



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



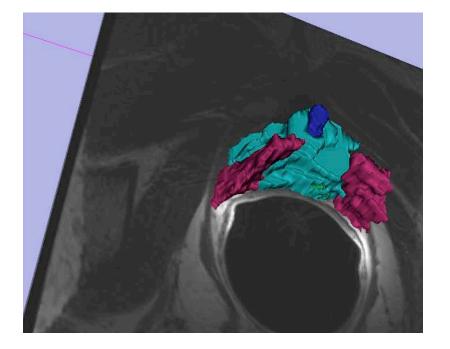
3. Manual segmentation of images



4. Creating 3D models from segmentations



Creating Models



We can create 3D models of the anatomy to enhance our visualization



Creating Models -Select Module

We will load the "Model Maker" module

The Model Maker module makes 3D triangulated surfaces from segmentations

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Creating Models -Select Module

Open the Model Maker module

(Other model choices may apply for other applications)

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Creating Models - Input Volume

Choose the input volume

This is the volume called "Label" in this demonstration

Each label value in the label map can be made into a surface model

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Creating Models - Hierarchy

Create a new model hierarchy

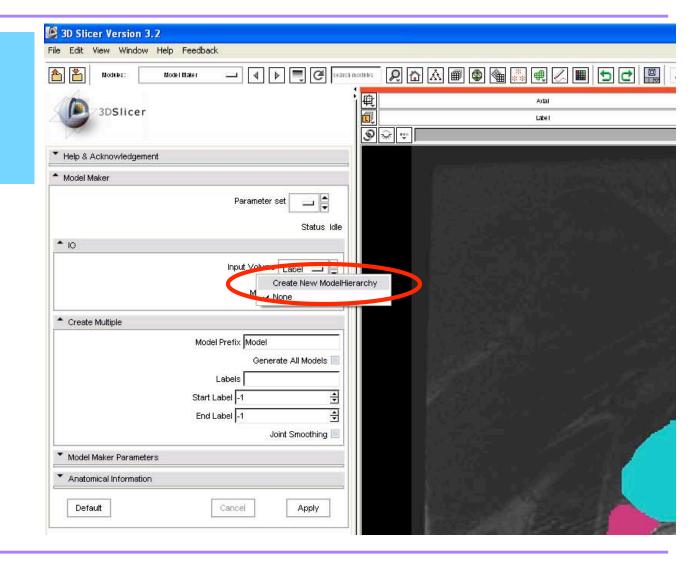
Hierarchies can be used to organize 3D models into groups

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Creating Models - Hierarchy

Select "Create New Model Hierarchy"





Creating Models - Generate

Generate models

Check the box "Generate All Models" box

(You could also generate models individually for each label value)

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Creating Models - Apply

Press the "Apply" button

Slicer will create all the models

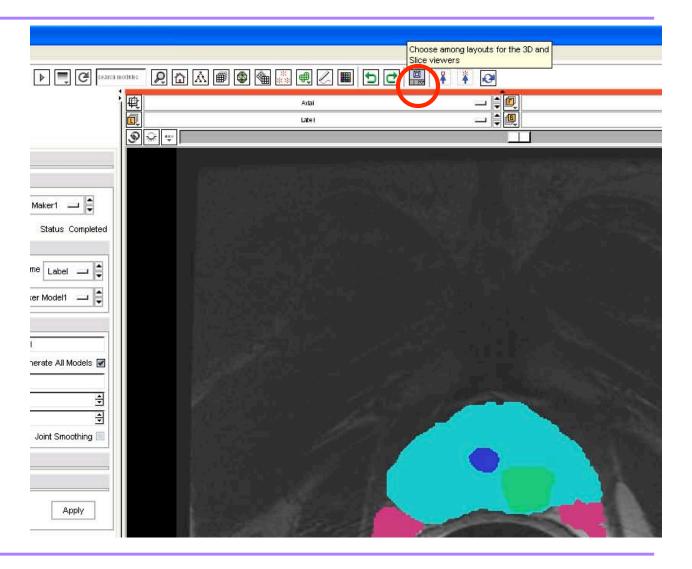
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Creating Models - View

View the models in 3D

We can visualize both the models and the image slices in 3D

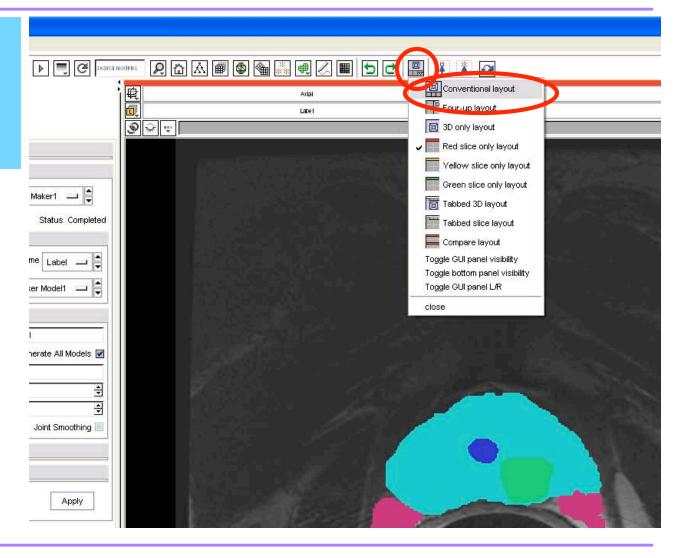


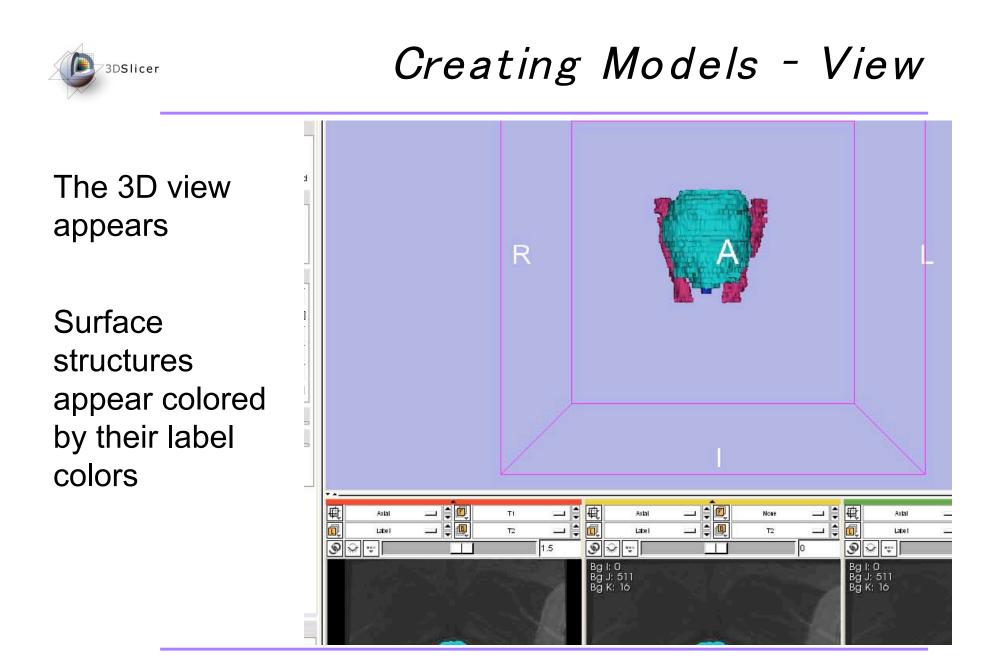


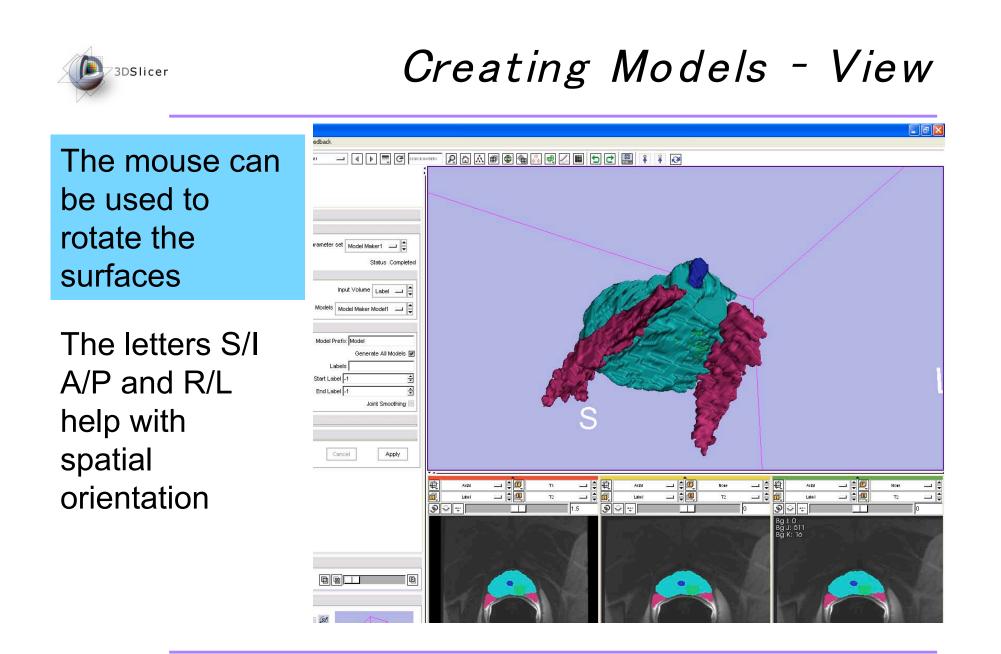
Creating Models - View

Select "Conventional Layout"

This view allows for viewing both image slices and 3D space



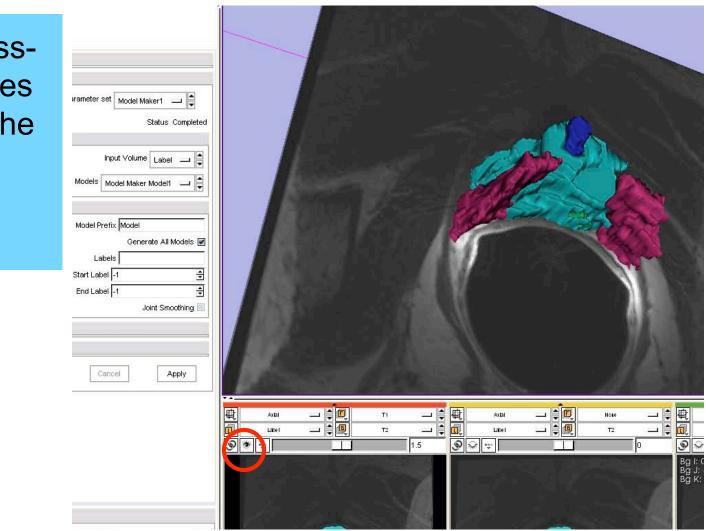






Creating Models - View

View the crosssectional slices by pressing the "eye" button above the slice(s)





Creating Models - Save

Save the models

The models need to be saved or they will be lost

Select "Save" from the "File" menu

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Creating Models - Save

Make sure "Save" is checked next to the models and "Save Scene"

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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 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).



Acknowledgements



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Neuroimage Analysis Center NIH P41RR013218



Morphometry Biomedical Informatics Research Network NIH U24RRO21382



Surgical Planning Laboratory (BWH) Clare Tempany, Nobuhiko Hata, Ron Kikinis



National Center for Image Guided Therapy NIH U41RR019703



NEDO Intelligent Surgical Instruments Project Kiyo Chinzei