

Diffusion Tensor Analysis in Slicer3

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Acknowledgments



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Neuroimage Analysis Center

NIH P41RR013218



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Laboratory of Mathematics in Imaging, Brigham and Women's Hospital NIH R01MH074794



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Material

• 3D Slicer3 (Release 3.2)

http://www.slicer.org/slicerWiki/index.php/Main_Page

- DTI Sample Data Set
 - Dwi-dicom.zip 256x256x36, 14 gradient directions
 - Case 1 (01053): 144x144x83, 58 gradient directions

- Surgery_format_case.zip 256x235x70, 59 gradient directions



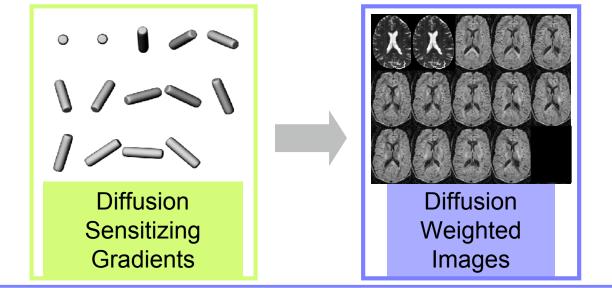
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Outline

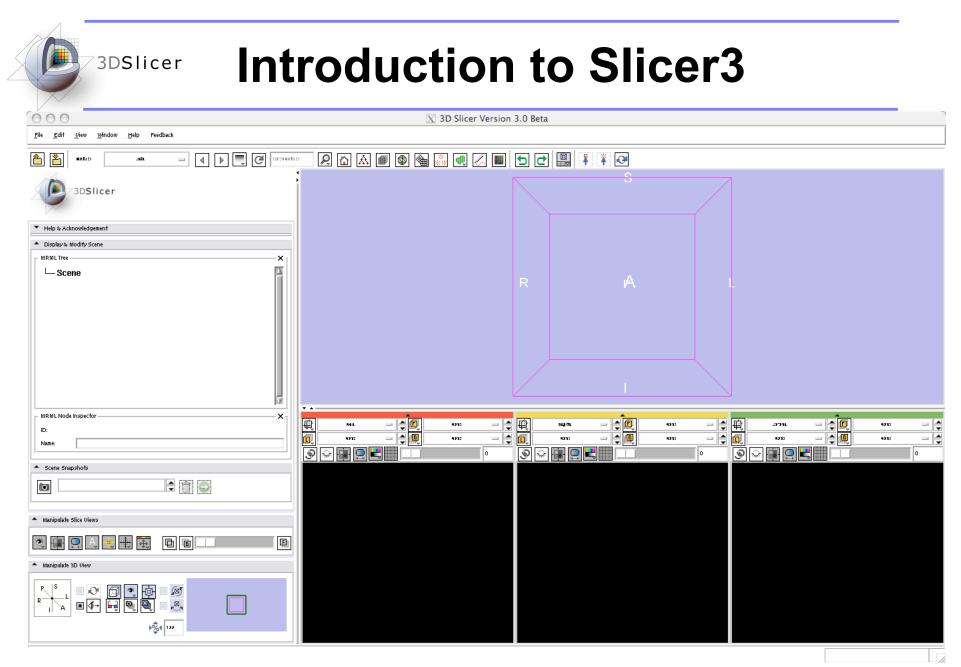
- Introduction to DWI and DTI
- Introduction to Slicer3
- DTI-related functionalities
- Loading DWI and tensor data
- Estimating tensors from DWI
- Visualizing tensors
- DTI tensor resampling
- Tractography

JDSlicer Introduction to DWI and DTI

- DWI (Diffusion Weighted Imaging) is a MRI modality that produces images describing the diffusion of water mollecules in tissues.
- The observed diffusion can vary with the orientation of the pulse gradient that is applied. This is due to anisotropy in water diffusion in tissues.
- Using different directions, different DWI images can be obtained.
 Each one describes diffusion in one direction.



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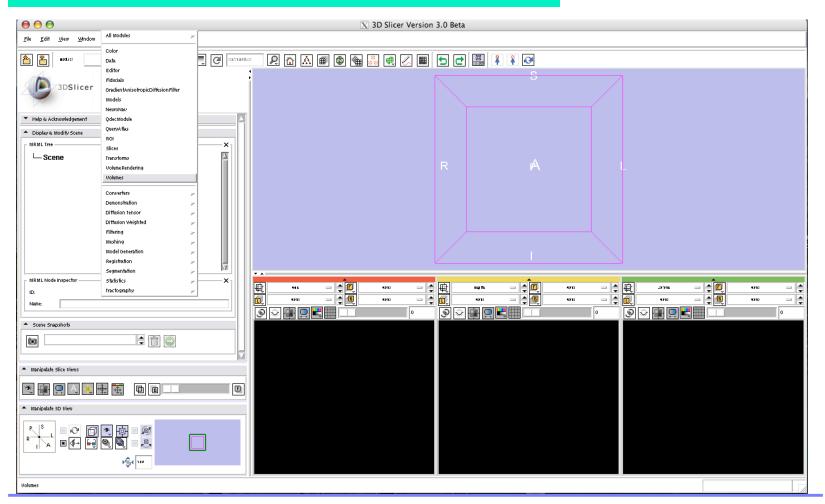
DTI-related functionalities

- Using Slicer3, you can:
 - Load DWI and tensor data. Load fiber tracts, and DTI-scenes
 - Estimate tensors from DWI data
 - Visualize tensors using scalar, color coding and glyphs (2D glyphs are new in Slicer3)
 - Resample DTI tensors
 - Perform tractography, using fiducials, label maps or stochastic tractography (new in Slicer3)

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JOSIICER Loading Dataset 1 (DWI data)

1- Select the module "VOLUMES" in the Modules menu

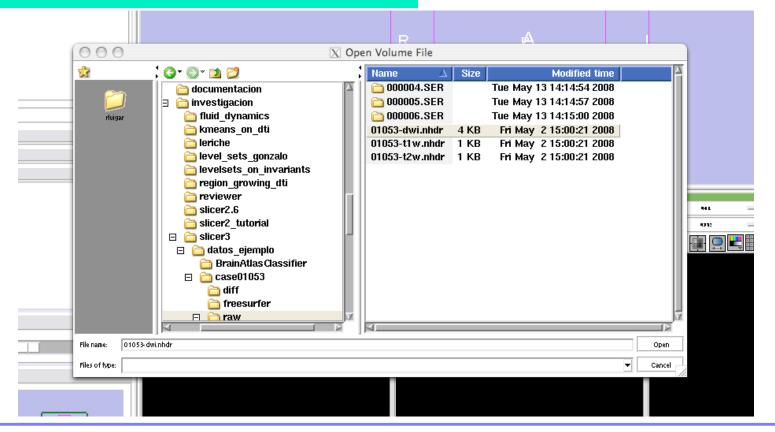


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JDSlicer Loading Dataset 1 (DWI data)

A dialog window will appear for you to select the header file when you click "Select Volume File"

2- Select the file "01053-dwi.nhdr"



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3DSlicer Loading Dataset 1 (DWI data)

The volume name will appear in the Load tag

2- Select "Image Origin"--> "From File" and click "Apply"

🔨 Help & Ackr	nowledgement
Load	
Select 1	Volume File
Volume Name:	01053-dwi.nhdr
Image Origin:	From File -
Label Map	
Api	viv vit
Active Volume:	
 Display 	
▼ Info	
▼ Save	

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JOSIICER Loading Dataset 1 (DWI data)

Once the dataset is loaded, three cuts will appear in the visualization area. 000 X 3D Slicer Version 3.0 Beta <u>File Edit V</u>iew <u>W</u>indow <u>H</u>elp Feedback 2 🛆 🛋 📾 🎕 🌉 🖉 💷 🛨 🔜 🖡 🏹 📤 🎽 🐽 NO 1827 3DSlicer Help & Acknowledgement 🚞 Select Volume File 01053-dwi.nhdr Volume Name-Image Origin: From File Single File 🔲 Label Map Apply Active Volume 01053-dwi.nhdr Display DWI Component Color Select Grey 🖌 Interpolate 食 - **.** - **.** 电记 僌 ÷ 0 - -- -617 Window/Level: Auto 1232 - -- 1 no di Ó 4212 nıs u - 12 1125 14 9 🖓 🖬 🛄 🗮 ☆ 🔳 🖸 💾 🏛 ତ୍ତ 🖬 📃 🗮 1.4211e 1-S - 5e-05 - 5e-05 19666 Threshold: off 🔤 🛛 0 [0, 19665] × [0, 1] Manipulate Slice Views E Manipulate 3D Vie »% III

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JDSlicer Loading Dataset 1 (DWI data)

The Display area allows the selection of the volume you want to visualize. There are 59 volumes for this dataset.

31	DSlicer	
Active Volume:	01053-dwi.nhdr	
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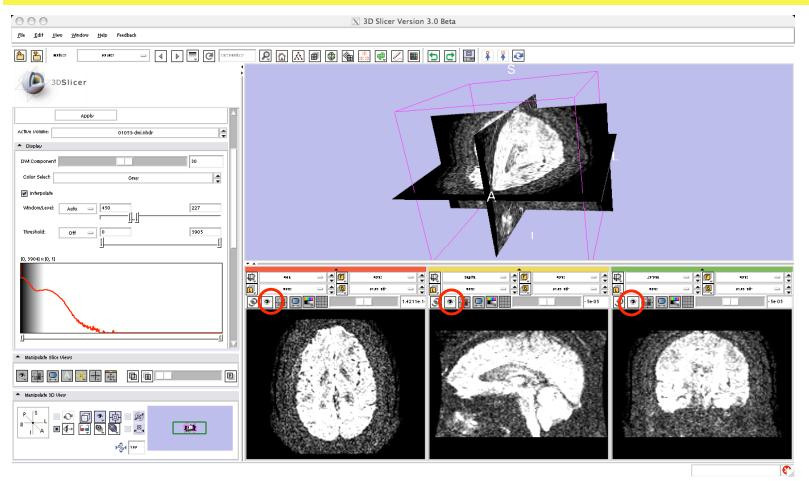
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4					(Þ
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Also, when a DWI volume is loaded, the "DWI Gradient Editor" tag becomes active. This can be used for converting DWI to tensors.

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JDSlicer Loading Dataset 1 (DWI data)

By activating the visibility button for each slice you can visualize slices in the main view.



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JDSlicer Converting from DWI to tensors

If a DWI volume is active, the "DWI Gradient Editor" tag is also active in the left panel.

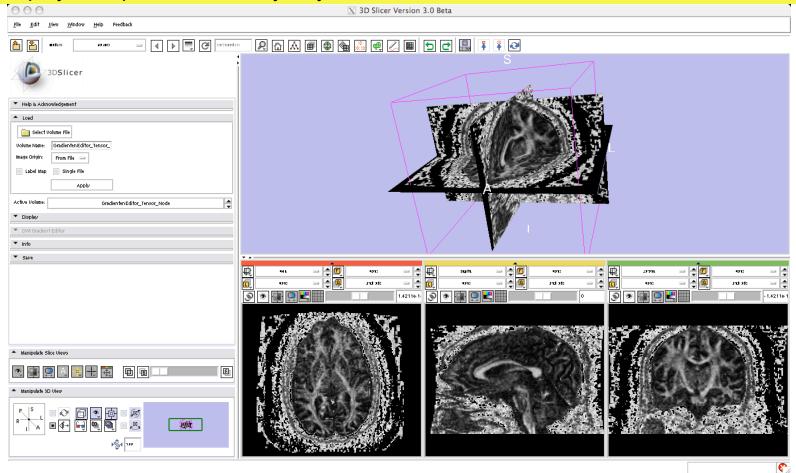
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To estimate the tensors, first unfold the TEST (Tensor Estimation & Tractography Fiducial Seeding) and then click "Run" to Estimate New Tensor

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^{73DSlicer}Converting from DWI to tensors

Once the estimation is performed, the tensor volume becomes active, and it can be displayed or processed in any way.

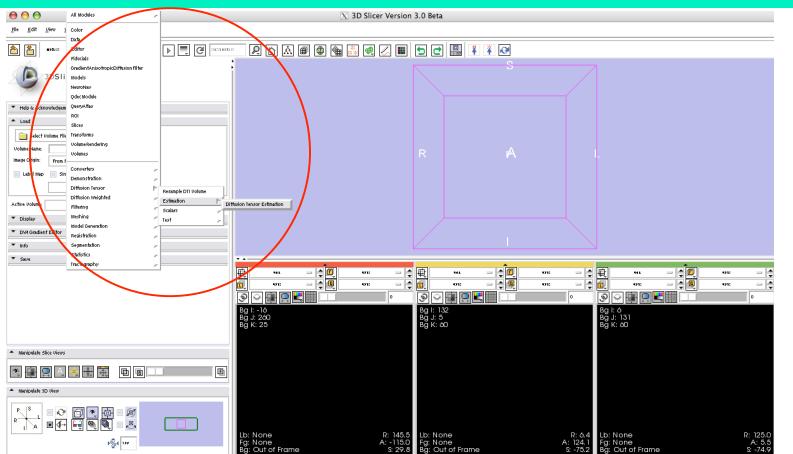


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3DSlicer Converting from DWI to tensors

Tensor estimation can also be performed from the DT-MRI module (you need to have an active DWI volume)

1- Select DIFFUSION TENSOR --> ESTIMATION --> DIFFUSION TENSOR ESTIMATION



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JDSlicer Converting from DWI to tensors

2- Unfold the Diffusion Tensor Estimation tag, and select names for the output volumes that will be created

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Estimation Parameters		Output Baseline Volume Diffusion Tensor Estimation Volume2 🔤 🚔
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Otsu Omega Threshold Parameter 0.5		Otsu Threshold Mask Diffusion Tensor Estimation Volume3 🥃 🚔
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Default Cancel Apply		Estimation Parameters 🔳 Least Squares 📄 Weigthed Least Squares 📄 Non Linear
		Otsu Omega Threshold Parameter 0.5
		Remove Islands in Threshold Mask 🗹
		Apply Mask to Tensor Image 🗹
		Default Cancel Apply
	3_ 5	Select the desired options and click "Apply"

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3DSlicer Converting from DWI to tensors

Once the tensor estimation has been performed, three volumes will become active:

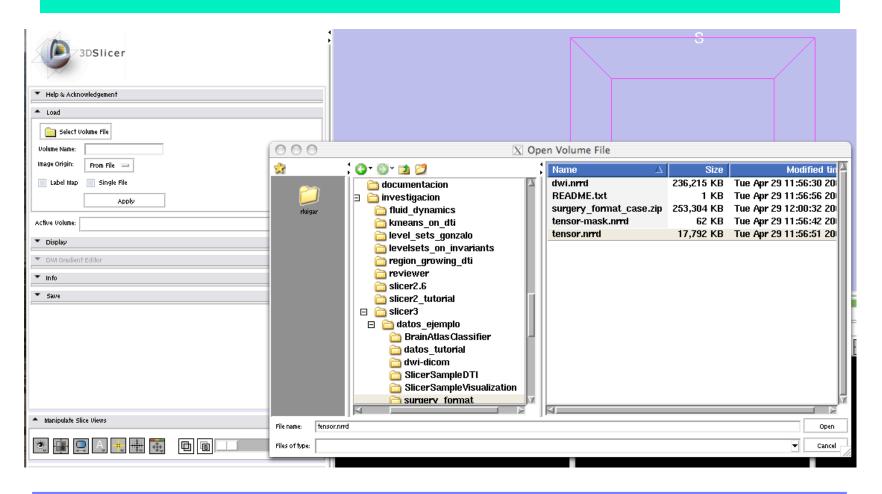
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Visualizing tensors

1- Load the tensor volume "tensor.nrrd" using the "Volumes" module



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Visualizing tensors

Once the tensor volume has been loaded, the "Display" tag will become active, offering different visualization options:

- Scalar measures (norm, trace, fractional anisotropy...)
- Color measures (orientation of the main eigenvector...)
- Glyphs

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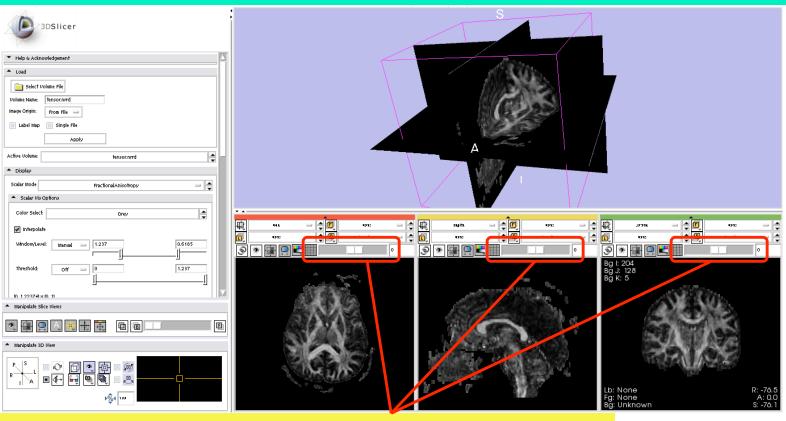
- Unfold the "Display" menu	3DSlicer
Solution	Help & Acknowledgement Load Select Volume File Volume Name: tensor.nrrd Image Origin: Prom File Label Map Single File Apply Active Volume: tensor.nerd Color Select: Grey Scalar Mode PractionalAnisotropy Scalar Mode PractionalAnisotropy Scalar Vis Options Color Select: Grey Interpolate Window/Level: Manual 1237 1237 1237 0.6185 1237 1237

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Visualizing tensors

3- Select "Scalar Mode"--> Fractional Anisotropy



You can navigate through the different slices using the slide bars

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Visualizing tensors

4- Using the same procedure, you can choose many other scalar measures to visualize

Apply		
Active Volume:	tensor.nmd_1	
▲ Display	 Trace Determinant 	
Scalar Mode Re	RelativeAnisotropy	
 Scalar Vis Options 	 FractionalAnisotropy 	
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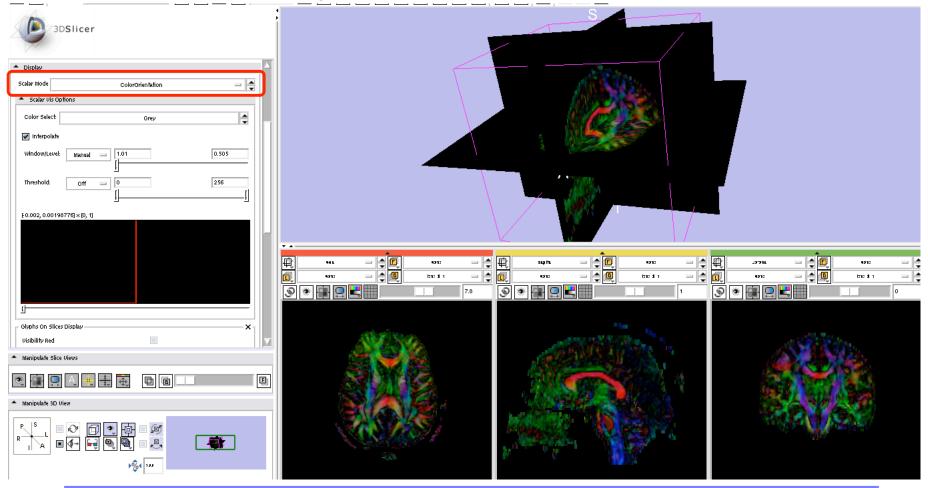
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Visualizing tensors

5- Select "Color Orientation": This is a color measure that color-codes the orientation of the main eigenvector of the tensor



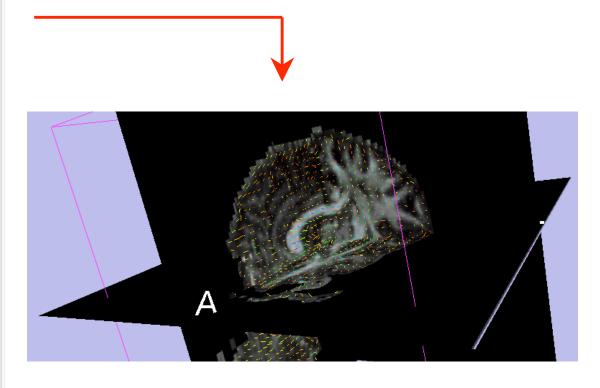
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Visualizing tensors

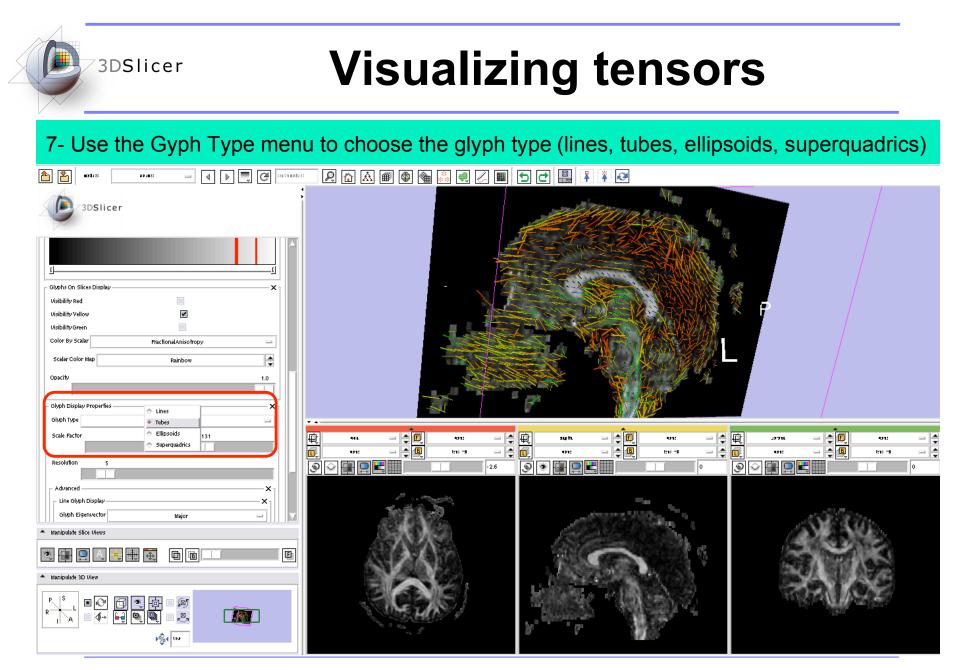
6- To visualize glyphs, activate the corresponding tags in the display menu

älyphs On Slices Display —	×
Visibility Red	
Visibility Yellow	
Visibility Green	
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Scalar Color Map	Rainbow
Opacity	1.0
Glyph Display Properties —	×
Glyph Type	Lines 🔤
Scale Factor	54
Resolution 4	
Advanced	×
Line Glyph Display	×_
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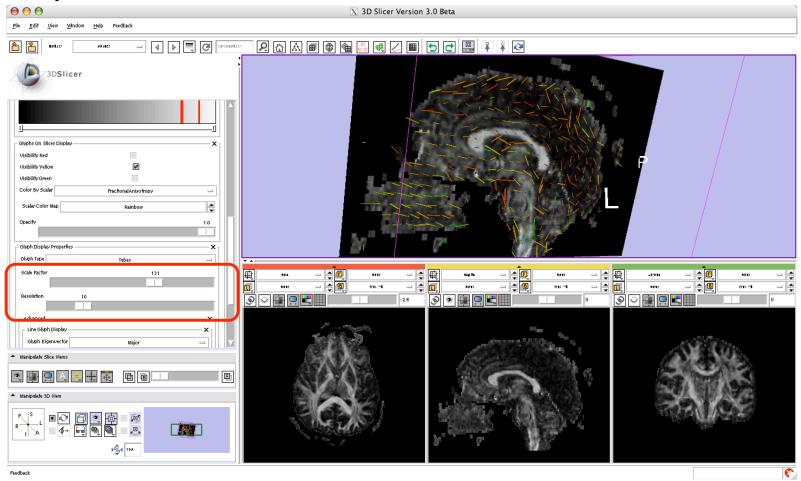


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⁷3DSlicer

Visualizing tensors

8- Use the Scale Factor and the Resolution controls to change the size and the density of Glyphs in your visualization.



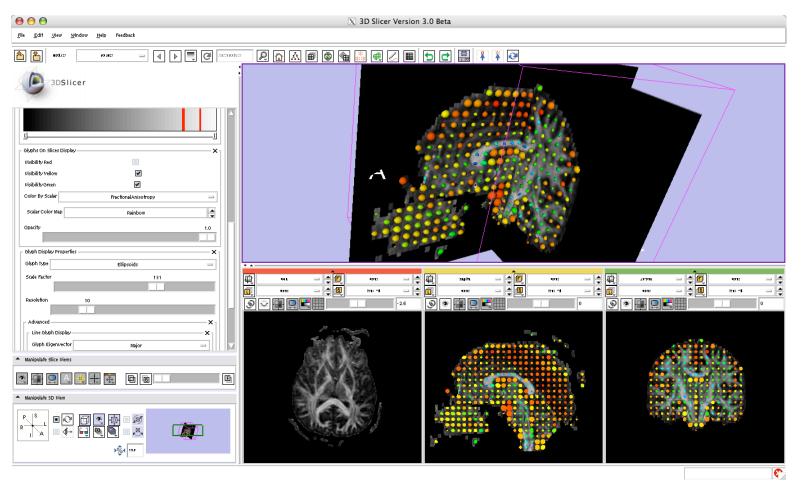
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Visualizing tensors

9- You can select to view glyphs in all three or only some of the slices, both in 2D views and the 3D view.



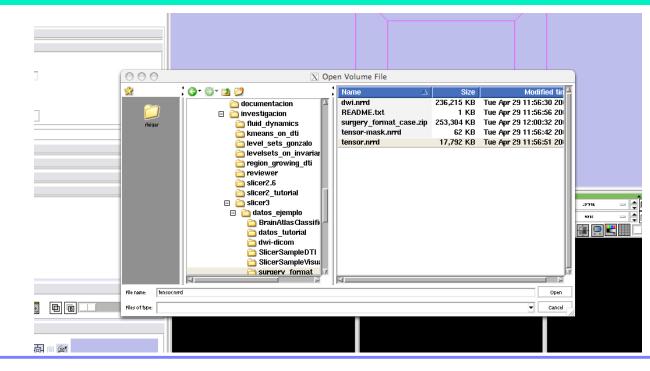
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DTI tensor resampling

With slicer3, you can apply transforms to a tensor volume:

- Rotations, translations.
- Rigid or affine transforms
- Linear interpolation, nearest neighbor, b-splines

1- Load a tensor volume to begin the process



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DTI tensor resampling

2- Select "Diffusion Tensor--> Resample DTI volume

3DSlicer

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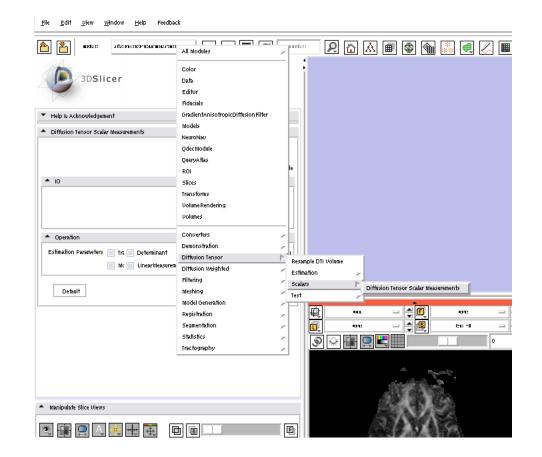
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3DSlicer DTI	ensor res	sam	
3- Load a pre-stored parameter set for the tensor	resampling		3DSlicer
4- Select the input tensor volume (the active one)	and an output volume		Help & Acknowledgement Resample DTI Volume
5- Number of threads for the computation of the te	•		Paraméter set Resample DTI Volume 1 🖃 🚔
			Status
6- Type of correction if a computed tensor is not S	PD		Input Volume tensor.nrd =
7- Select slicer transform			Output Volume Resample DTI Volume Volume 1 🔤
8- Transformation matrix (rotation and translation)			Reference Volume (To Set Output Parameters) None
			Number Of Threads 0
9- Transformation type (rigid/affine)		$\langle \rangle \rangle \langle \rangle$	Correction zero 🔳 none 📄 abs 👘 near
10- If the transform is in RAS (slicer), or LPS(itk)	oordinate system		Transform Barameters Transform Node None
11. Define contain of the setting (fight side on a	we a constant		Manual Transform (Used Only If No Transform Node Set)
11- Define center of transformation (fiducial or vol	ume center)		Transform Matrix 1,0,0,0,1,0,0,0,1,0,0,0
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	at the factor of the factor of		Rigid/Affine Parameters
11- Type of interpolation performed (linear, neare windowed sinc, B splines)	st neignbor,		Rotation Center None -
windowed sinc, b spilles			Centered Transform Inverse Transformation
12- Window function for the windowed sinc interpo	plation		Affine Transform Parameters
(Hamming, cosine, Welch, Lanczos, Blackman)		\setminus \setminus	Preservation of Principal Direction Interpolation Type
			Interpolation Type
13- Spline order for the B splines interpolation			 Windowed Sinc Interpolate Function Parameters
14- General parameters of the output volume			Window Function h 🔳 c 🔤 w
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		$\langle \rangle$	Spline Order 3
		\	Output Parameters
30- Surgical Planning Laborator	v	\backslash	Spacing (0,0,0 Size (0,0,0
http://www.slicer.org	3		Origin None 📼



DTI scalar measurements

1- Select the module "Diffusion Tensor Scalar Measurements"



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DTI scalar measurements

2- Select the options:-Input DTI volume: tensor.nrrd-Output Scalar volume: new volume-Estimation parameters:

- Trace
- Determinant
- Relative Anisotropy
- Fractional Anisotropy
- Mo....
- Linear Measurement
- Planar Measurement
- Spherical Measurement

- Click Apply

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	3DSlicer
	Help & Acknowledgement
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	Output Scalar Volume Diffusion Tensor Scalar Measurements Volume 1 🔤 🚔
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	🔳 Mc 📃 LinearMeasurem 📃 PlanarMeasurem 📃 SphericalMeasurem
	Default Cancel Apply

DTI scalar measurements

The resulting scalar volume can be displayed, stored, futher processed...

Window Help Feedback 🔹 🕨 📃 🧭 samadas apd122 u filo par enconstante esta tarente 👘 👘 3DSlicer Help & Acknowledgement Diffusion Tensor Scalar Measuremen Parameter set Diffusion Tensor Scalar Measurem Status Completer **A** 10 Innut DTL U Output Scalar Volume Diffusion Tensor Scalar Measurements Volume 1 Operation Estimation Parameters Tra Determinant RelativeAnisotro PractionalAnisotro 🔳 Mc 👘 LinearMeasurem 👘 PlanarMeasurem 👘 Spherical Default Cancel Apply и**П 1**121 4 ī) 9 * 9 🖲 🖬 🖳 🗮 ے 🗨 🖷 🔍 🛃 Manipulate Slice Diews ÷ E Manipulate 3D Die fa 1 **1**.1.1

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Tractography

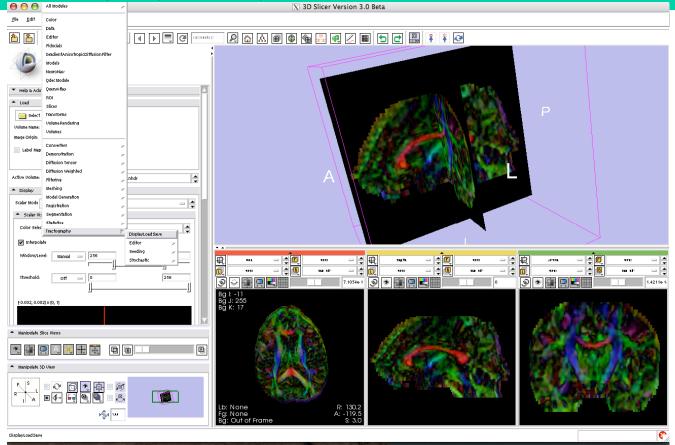
With slicer3, you can:

- Load and display previously obtained tracts.
- Create new tracts, using:
 - Fiducial seedings
 - ROIs
 - Stochastic Tractography
- Save the tracts you have obtained

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Loading and displaying tracts

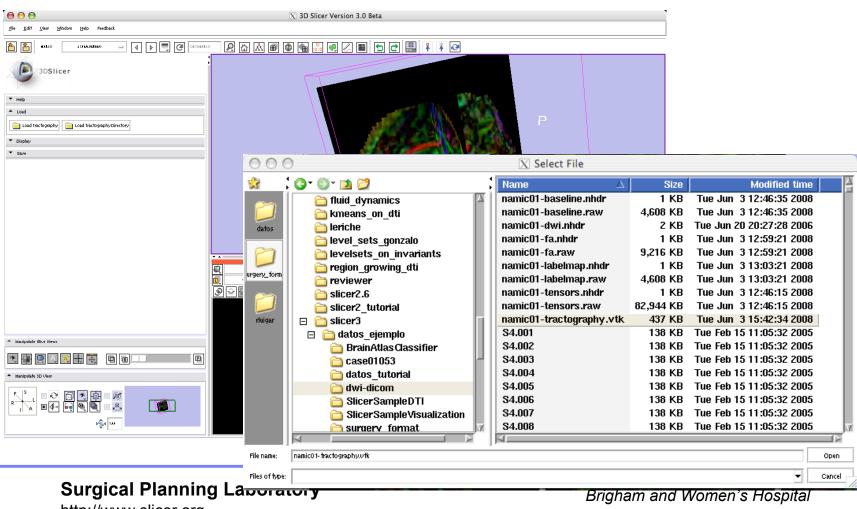
- 1.- Load the tensor volume dwi-dicom.
- 2.- Visualize the tensors in your preferred way (color orientation, for instance).
- 3.- Go to Tractography -> DisplayLoadSave



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Loading and displaying tracts 3DSlicer

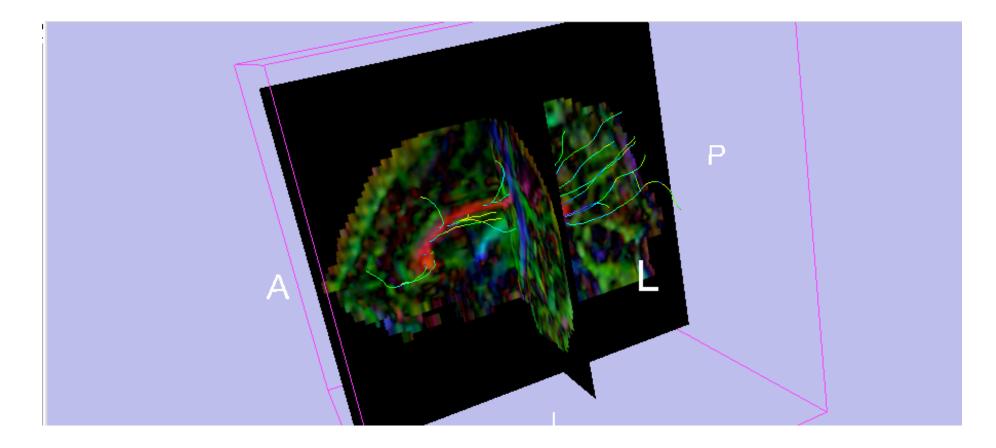
- 4.- Click on "Load Tractography"
- 5.- Load the file namic01-tractography.vtk



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The loaded tracts will appear in the 3D view



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Loading and displaying tracts

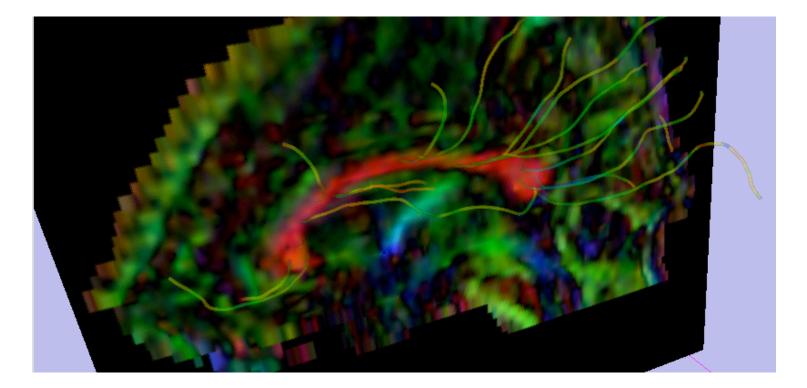
Unfold the Display tag from the tractography module

iberBundle Select:	namic01-tractography.vtk	
isplay For:	Tube	=
Tube Display		x
Visibility		
Color By Scalar	FractionalAnisotropy	
Scalar Color Map	Rainbow	
Clipping		
Opacity		1.0
Set Color Glyph Display Properties		X
Glyph Type	Lines	=
Scale Factor	50	
Resolution	20	
Advanced		-

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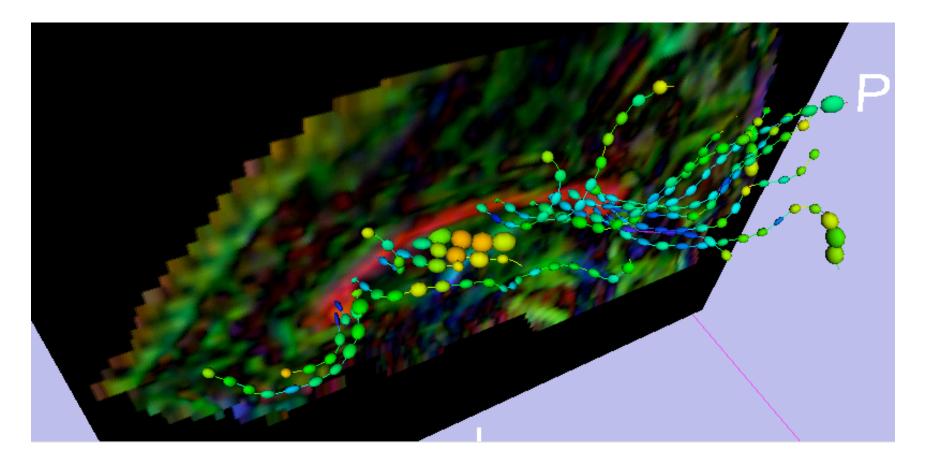
Loading and displaying tracts

Using the controls, you can display Tubes, Lines and Glyphs, and can control the Appearance of each of them (scale, color, opacity...)



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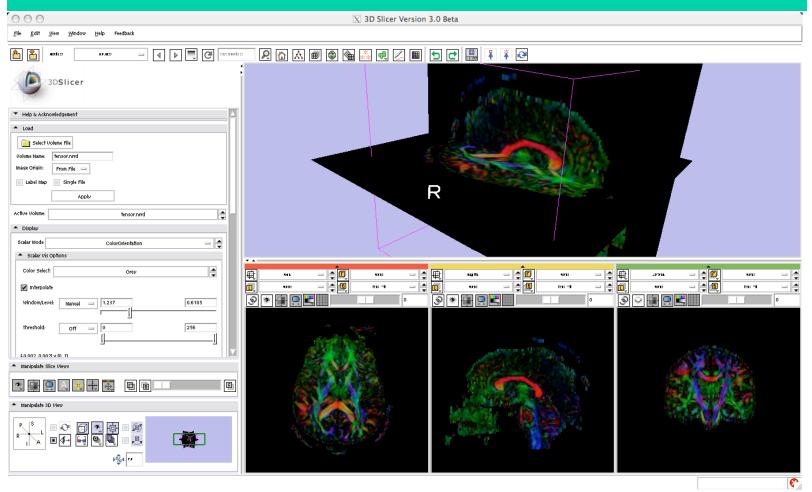


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Performing tractography with fiducial seedings

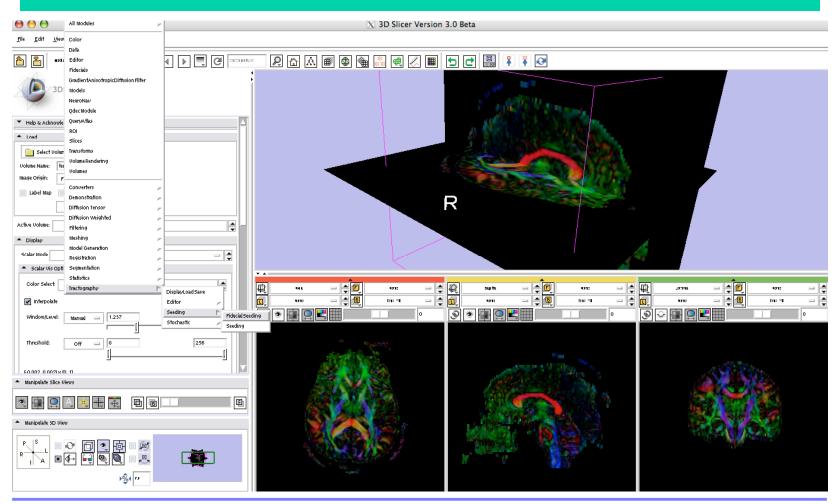
1.- Visualize the tensor volume in the most appropriate way to select fiducials



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Performing tractography with fiducial seedings

2.-Select the module Tractography --> Seeding --> Fiducial Seeding



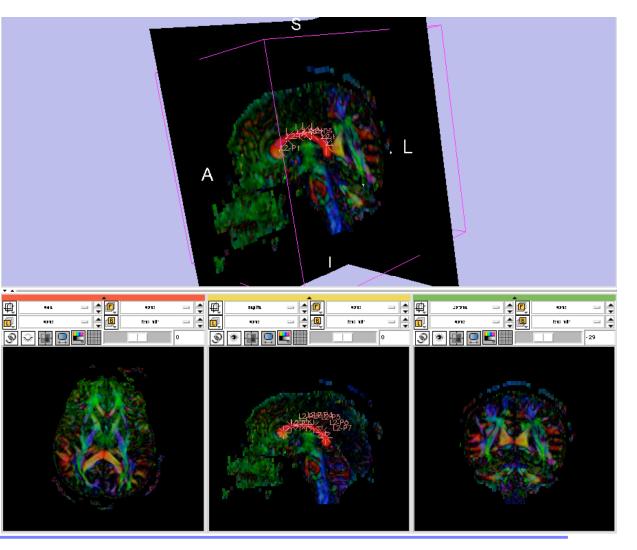
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Performing tractography with fiducial seedings

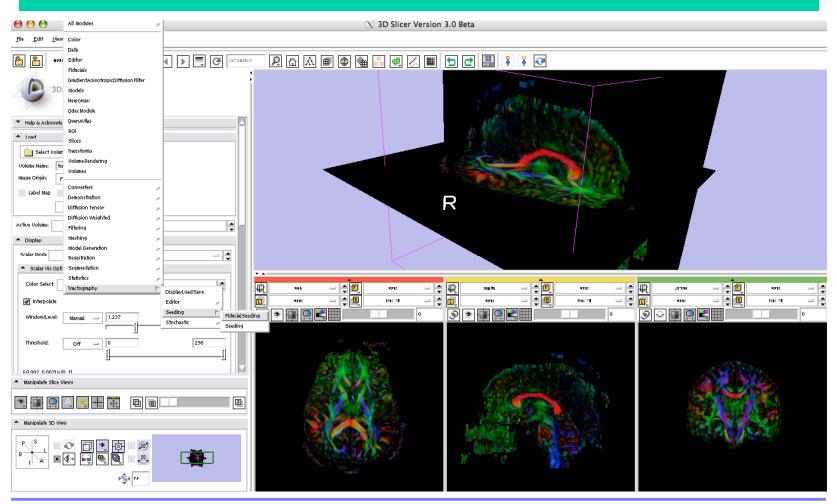
2.-Select as many fiducials as you want by clicking with the mouse and pressing "P" (both in the 2D views or in the 3D view)



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Performing tractography with fiducial seedings

3.-Select the module Tractography --> Seeding --> Fiducial Seeding



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Performing tractography with fiducial seedings

3.-Select the tensor volume on which tractography will be performed.Select the fiducial list, and the name of the Output Fiber Bundle.

3DSlicer

Other parameters can be adjusted and readjusted interactively.

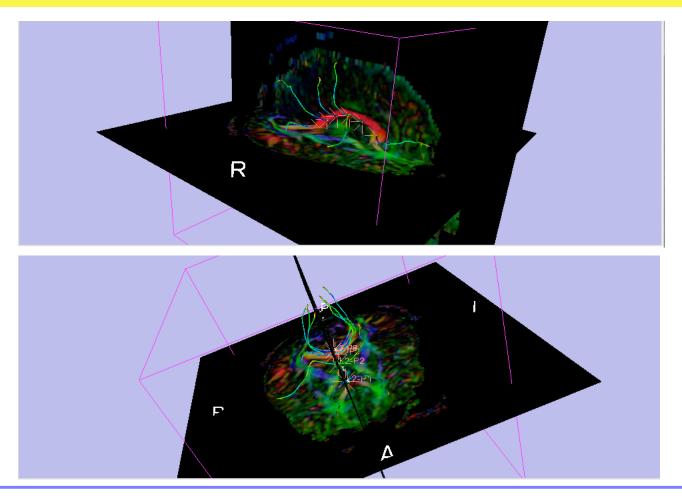
3DSlicer
Help & Acknowledgement
 Tractography Seeding From Fiducial
Select DTI Volume: 🛛 tensor.nmd 🛁 🚔
Select Fiducial List 🛛 🗖 🚍
Output FiberBundleNode: 🛛 FiberBundleNode2 🛁 🚔
Stopping Mode: Linear Measurement 📟
Stopping Value 0.3
Stopping Track Curvature 0.8
Integration Step Length (mm) 0.6
Seed Tracts

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Performing tractography with fiducial seedings

The obtained fibers will appear in the 3D view, toghether with the fiducial seeds.

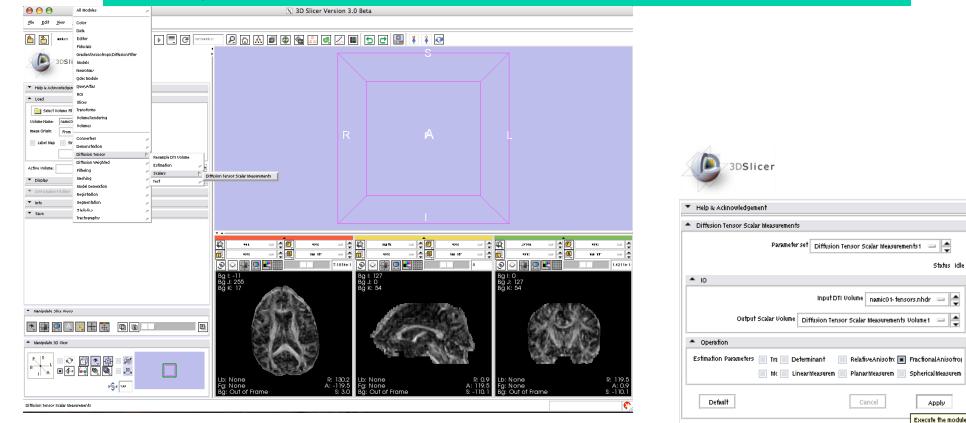


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Performing tractography with ROI seeding

1.- Load a tensor volume: dwi-dicom

2.- Obtain an appropriate scalar measure for the delineation of the ROI (fractional anisotropy, for instance).

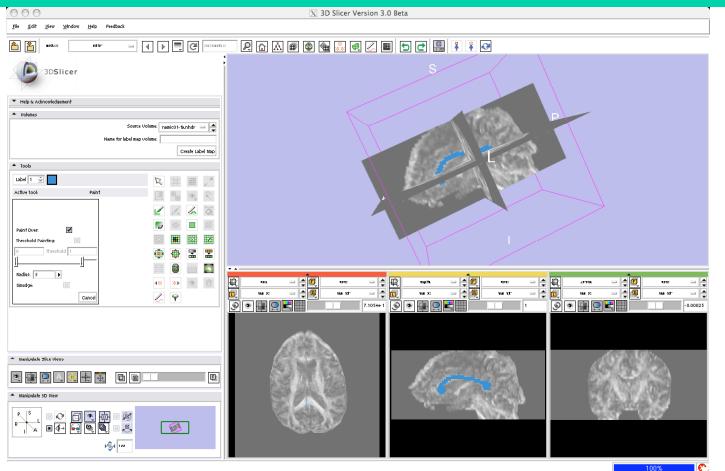


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Performing tractography with ROI seeding

3.- On the scalar measure, use the Editor module to create a label map delineating the ROI. Save it.

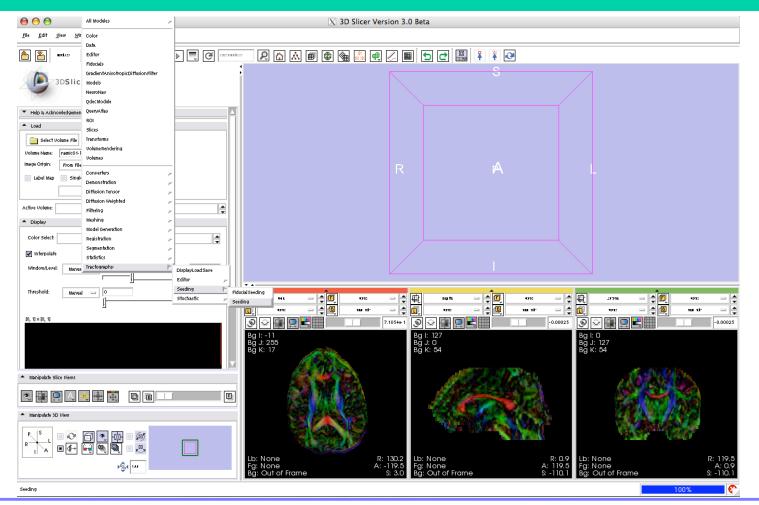


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Performing tractography with ROI seeding

4.- Select the module Tractography -> Seeding -> Seeding



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Performing tractography with ROI seeding

5.- Select the parameters, and click Apply

3DSlid	er
• 10	
	Input DTI Volume 🛛 namic0 1- tensors.nhdr 🛛 🖃 🛃
	Input ROI namic01-labelmap.nhdr-label 🔤 🞑
	Output Fiber bundle 🛛 Seeding Model 1 🔤 🚔
	Write Fibers To Disk 📃
	Output Directory 🚞
	File Prefix Name line
 Seed Placement Optio 	ns
	Seed Spacing 5
	Random Grid
	Linear Measurement Start Threshold 0.3
 Tractography Seeding 	Parameters
	Minimum Length 10 🕨
	Maximum Length 800
	Stopping Mode 🔳 LinearMeasurement 📄 FractionalAnisotropy
	Stopping Value 0.1
	Stopping Track Curvature 0.8
ROI Definition	
	ROI label 1
Default	Cancel Apply

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Brigham and Women's Hospital

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Performing tractography with ROI seeding

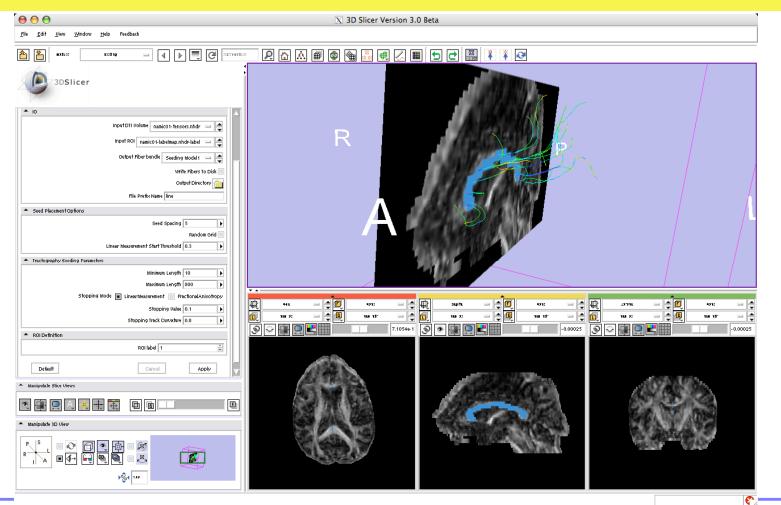
The obtained tracts will appear in the 3D view. 000 X 3D Slicer Version 3.0 Beta <u>F</u>ile <u>E</u>dit <u>V</u>iew <u>W</u>indow <u>H</u>elp Feedback = 🖌 🕨 🗮 🤁 scrudes <u> 1</u> 🔎 🟠 🔎 🚳 🍓 💑 🖳 🖉 🖿 🔁 🖳 🖡 🧍 🧭 mpd1122 seet na 3DSlicer Input DTI Volume 🛛 namicü 1- tensors.nhdr 🛛 🖃 🚔 Input ROI namic01-labelmap.nhdr-label 😑 Output Fiber bundle Seeding Model 1 Write Fibers To Disk Output Directory File Prefix Name line Seed Placement Options Seed Spacing 5 Random Grid Linear Measurement Start Threshold 0.3 Tractography Seeding Parameters Minimum Length 10 Þ Maximum Length 800 Stopping Mode 🔳 LinearMeasurement FractionalAnisotrops 龟 僌 **. 1** - 1 ang itu - 4 僌 - 😫 🗖 471 Stopping Value 0.1 Þ - uff ner 10 22 - -10.2 - 1 đ, J 🕅 🖬 21 - 1 - |\$ 10 22 uff agr Stopping Track Curvature 0.8 Þ ୭ 🖬 🖪 🗮 🖩 7.1054e 1 ے 🔄 📄 🖓 . 📺 . 🔘 🛃 -0.00025 -0.00025 ୍କ * ROI Definition ROI label 1 Default Apply Intanipulate Slice * 🔳 📮 • • • • • Đ Manipulate 3D Vi - (oj **▶ 💏 1** 1.11

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Performing tractography with ROI seeding

You can visualize the tracts together with the tensor volume, the label map...



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