Diffusion Tensor Imaging tutorial

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DTI tutorial

This tutorial is an introduction to the advanced Diffusion MR capabilities of the Slicer3 software for medical image analysis.
Outline

This tutorial guides you through the process of loading diffusion MR data, estimating diffusion tensors, and performing tractography of white matter bundles.
Outline

The processing pipeline uses 9 image analysis modules of Slicer3.6

1. Data
2. Volumes
3. Diffusion Tensor Estimation
4. Diffusion Tensor Scalar Measurements
5. Editor
6. LabelMap Seeding
7. Fiber Bundles
8. Fiducials
9. Fiducial Seeding
Tutorial Dataset

The Diffusion MR tutorial dataset is composed of a Diffusion Weighted MR scan of the brain acquired with 12 gradient directions and 2 baseline.

Diffusion Sensitizing Gradients

Diffusion Weighted Images
DTI Processing Pipeline

- DWI Acquisition
- Tensor Calculation
- Scalar Maps
- 3D Visualization
Start Slicer3

**Linux/Mac users**
Launch the Slicer3 executable located in the Slicer3.6 directory

**Windows users**
Select
Start → All Programs → Slicer3-3.6-RC3-2010-06-04 → Slicer3
Slicer Welcome

The SlicerWelcome module is the module displayed by default. This module gives an overview of the GUI of Slicer3, and data loading & saving functionalities.
Part 1:

Diffusion data loading and tensor estimation
Diffusion Tensor

Stejskal-Tanner

\[ S_i = S_0 e^{-b\hat{g}_i^T \mathbf{D} \hat{g}_i} \]

\[ \mathbf{D} = \begin{bmatrix}
D_{xx} & D_{xy} & D_{xz} \\
D_{yx} & D_{yy} & D_{yz} \\
D_{zx} & D_{zy} & D_{zz}
\end{bmatrix} \]
Loading the DWI volume

Select **File ➔ Add Volume** from the File menu.
Loading the DWI volume

Browse to the location of the Diffusion tutorial dataset directory and select the file dwiDataset.nhdr

Click on **Apply** to load the volume
Loading the DWI volume

Slicer displays the anatomical views of the baseline volume of the diffusion dataset in the 2D Slice Viewer.
Tensor Estimation

Left click on the menu **Modules** and select **All Modules** to display the list of **95 modules** available for image analysis and 3D visualization.

Select the module **Diffusion Tensor Estimation**.
Tensor Estimation

Select the Input DWI Volume `dwiDataset`

Left click on **OutputDTIVolume** and select ‘Create New Diffusion Tensor Volume’

Left click on **Output Baseline Volume** and select ‘Create New Volume’

Left click on **Otsu Threshold Mask** and select ‘Create New Volume’
Select the Tensor Estimation Algorithm \textbf{LS} (Least Squares), and click on \textbf{Apply} to estimate the tensors.
Tensor Estimation

Left click on **Diffusion Tensor Volume 1** to display the list of volumes that have been computed by Slicer.
Tensor Estimation

Diffusion Tensor Estimation Volume is the volume of estimated tensors

Diffusion Tensor Estimation Volume 1 is the Baseline volume

Diffusion Tensor Estimation Volume 2 is the tensor mask (blue)
Tensor Estimation

Click on the link icon, left click on **Diffusion Tensor Volume 2** and select **None**
Tensor Estimation

Select the module **Volumes** in the modules’ toolbar
Tensor Estimation

Select the Active Volume ‘Diffusion Tensor Estimation Volume 1’ and click on the tab Display
Tensor Estimation

Adjust the Window/Level parameters of the baseline volume using the slider.
Tensor Estimation

Browse through the baseline images, which correspond to the volumes that have been acquired without gradient.
Part 2: Scalar Measurements
Scalar Measurements

Select the category **Diffusion--> Utilities** from the list of modules, and left click on the **Diffusion Tensor Scalar Measurements** module.
Scalar Measurements

Select the Input DTI Volume **Diffusion Tensor Estimation Volume**

Select the Output Scalar Volume ‘Create New Volume’

Select the Operation **Fractional Anisotropy**, and click on **Apply**
Fractional Anisotropy Volume

Left click on the Slicer Viewer Menu icon, and select **Show label volume outlines**
Slicer displays the outline of the tensor mask overlaid on the Fractional Anisotropy volume.
Move the mouse over the Fractional Anisotropy map to explore the FA values which range from 0 to 1, and are displayed in the bottom corner of the active (Bg) window.
Part 3:
Region of Interest based Tractography
LabelMap Generation

Select the module **Editor** in the modules menu.

Select the Master Volume as **Diffusion Tensor Scalar Measurements Volume**.

Click 'Set', then left click on 'Diffusion Tensor Estimation Volume 2' in the popup box. Click 'Rename' and rename it as 'Working'.
LabelMap Generation

Now click on **Create New** in the same popup box. Left click on the dropdown box and select **Discrete** and then select **Labels**. Click **Apply**.
LabelMap Generation

Left click on the Slicer Viewer Menu icon, and select **Don’t Show label volume outlines**
LabelMap Generation

Select the label 2 (pink), click on the icon Paint, set the radius to 2 and draw a region of interest within the corpus callosum in the sagittal view on a few slices.
LabelMap Seeding

Select the module **Labelmap Seeding** from the Modules’ menu
LabelMap Seeding

Select the Input DTI volume ‘Diffusion Tensor Estimation Volume’

Select the Input Label Map ‘Working’

Select Output Fiber Bundle ‘Create New Fiber Bundle’
LabelMap Seeding

Set the Seed Spacing to 2 mm and select the Stopping Mode **Fractional Anisotropy**

Use the default parameters for the minimum and maximum tract length, stopping value and stopping track curvature.

Set Seeding label to label 2, and click on **Apply**
LabelMap Seeding

The tracts generated within the corpus callosum region appear in the 3DViewer.

The color map used represent the FA values along the tracts.
LabelMap Seeding

Select the module **FiberBundles**, and click on the tab **Tube** in the Display panel.

Check the Visibility box.
LabelMap Seeding

Slicer displays the computed tracts as tubes colored with FA values.
Part 4:

Tractography on-the-fly
Fiducial Seeding

Select the module Fiducials
Fiducial Seeding

Set Fiducial List to Create New Fiducial List
Fiducial Seeding

Left click on **FiducialList** and select Rename
Fiducial Seeding

Enter the new name **Seed** and click on **Apply**
Fiducial Seeding

Click on the cross icon to add a fiducial to the list Seed
Fiducial Seeding

The fiducial Seed-P appears in the 3D Viewer.
Fiducial Seeding

Position the fiducial in the cingulum region located above the corpus callosum.
Fiducial Seeding

Select the **Seed-P** fiducial: we will use this fiducial to drive the tractography.
Fiducial Seeding

Select the module Fiducial Seeding
Fiducial Seeding

Set the DTI Volume to Diffusion Tensor Estimation Volume

Select the Fiducial List Seed

Set the Output FiberBundleNode to Create New FiberBundle
Fiducial Seeding

Set the Stopping Mode to Fractional Anisotropy and set the tractography parameters to the values that we used for the corpus callosum:

**Stopping Value:** 0.1

**Stopping Track Curvature:** 0.8

**Step Length:** 0.8 mm

**Minimum Path Length:** 10 mm

**Fiducial Stepping Size:** 1.5 mm
Fiducial Seeding

Slicer displays the tracts seeded from the Fiducial Seed-P.

The tracts correspond to the region of the cingulum located above the corpus callosum.
Fiducial Seeding

Move the fiducial **Seed-P** from the left cingulum to the corresponding region in the right cingulum in the coronal slice.
Fiducial Seeding

Slicer displays the right cingulum tracts which are seeded from the new position of the fiducial Seed-P.
Part 5:

Saving a DTI Scene
Select the module Data

Slicer displays the list of volumes and models generated in this tutorial
Saving a DTI Scene

Select File → Save from the main menu
Saving a DTI Scene

Browse to a directory where you would like to save the data. Once you have selected a directory, click on **Save Selected**
Saving a DTI Scene

Select **File → Close Scene** to close the current DTI Scene.
Loading a DTI Scene

Select File → Load Scene and browse to the location where you saved the scene SlicerScene1.mrml
Loading a DTI Scene

Select the scene SlicerScene1.mrml and click on Open
Loading a DTI Scene

Select the module Data
Loading a DTI Scene

Slicer loads all the elements of the DTI Scene that were previously computed.
Conclusion

This tutorial guided you through some of the Diffusion MR capabilities of the Slicer3 software.

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