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Slicer3 Tutorial / Registration Library: Case 03 - DTI

aligning low-resolution diffusion MRI

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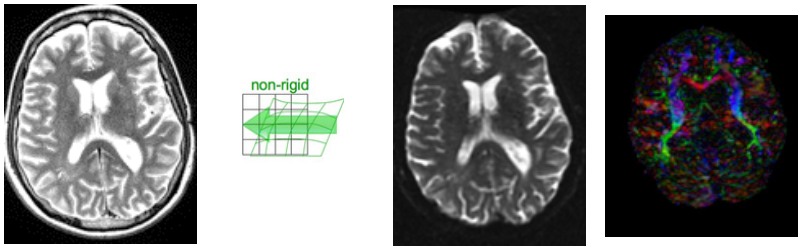
Sept. 2010

Introduction / Scenario

- We have a low resolution DWI scan we seek to align with the structural reference T2 scan
- The DWI scan has a strong rotational misalignment and also strong voxel anisotropy. Both cause problems downstream for obtaining an accurate registered DTI and hence have to be corrected beforehand.



T2 reference

0.4 x 0.4 x 1.5 mm

DTI baseline

DTI tensor

0.9375 x 0.9375 x 3 mm

Modules Used

- To accomplish this task we will use the following modules:
  - Volumes Module 
  - Diffusion Tensor Estimation Module 

  - BrainsFit Registration Module 

  - Data Module 
  - Resample DTI Module 

Prerequisites

- Slicer version 3.6.1 or later
- Example Dataset: download and extract the dataset for this tutorial: RegLib_C29_DATA.zip, which should contain this tutorial, all original and some intermediate solution data files.
- The extension set RegLib_C29_DATA_DWI.zip contains the original DWI image and the resampled DTI image (omitted from main set to maintain moderate dowload sizes).
- Tutorials to complete first (optional):
  - Slicer3Minute Tutorial
  - Loading and Viewing Data
  - DTI tutorial

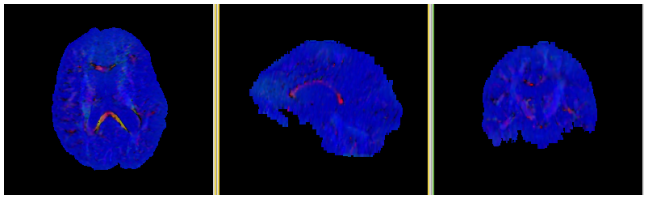
Pipeline

	Step	Module	Result	Slides
1	Resample T2 to isotropic voxel size 1x1x1	Resample Scalar Volume	T2.nrrd	7
2	Manually align DWI with T2	Transforms	Rigid transform node: Xf1_ManualInit.tfm	8
3	Resample DWI to T2 space and isotropic voxel size	Resample Scalar/Vector/DWI Volume	resampled DWI volume	8
4	Obtain DTI Estimation	Diffusion Tensor Estimation	DTI.nrrd	9-10
6	Register Baseline DTI to resampled T2	Registration / BrainsFit	nonrigid Bspline transform: Xf2_DTI-T2_unmasked, Xf3_DTI-T2_masked	11-15
7	Resample DTI	Diffusion / Utilities / Resample DTI Volume	Resampled DTI in space of T1: DTI_Xf3	16

Preprocessing

The original DWI image has two characteristics that cause problems downstream and hence should be corrected first:

1. Resolution is 1 x 1 x 3 mm , which in combination with the strong rotation will cause strong “bleeding” of the z-direction when resampling
2. The volume has a strong rotation around the LR axis, which causes problems when creating the DTI tensor



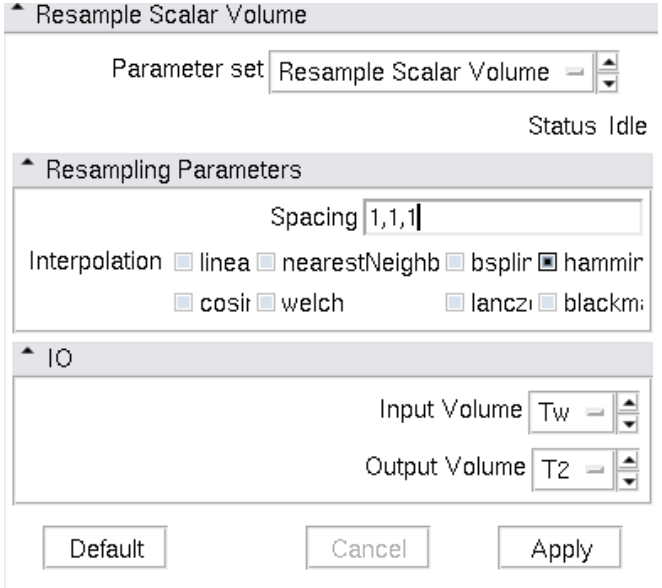
If the original DWI is used to obtain a DTI, which in turn is registered to the T2, the strong anisotropy in the DWI image will cause interpolation artifact with a strong “blurring” of the directional (z (IS)) component, ultimately yielding the biased image above. To prevent this we make the DWI isotropic first and then also align it manually to the T2.

We address the misalignment via a rough manual alignment and the resampling to isotropic voxels at the same time when resampling the DWI with this transform

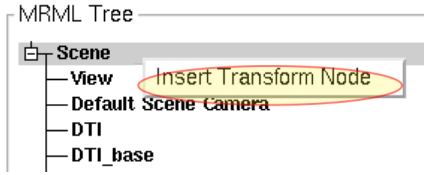
Preprocessing: Resample T2

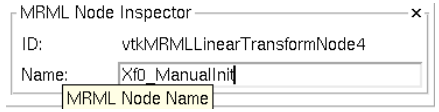
1. Go to the *Resample Scalar Volume* module:
   Input Volume: T2_raw
   Resampling Parameters: Spacing = 1, 1, 1
   Interpolation: “hamming”
   Ouput Volume: “Create New Volume”, rename to “T2”

2. Click “Apply”



Preprocessing: Manual Alignment

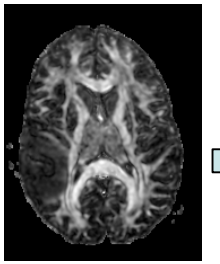




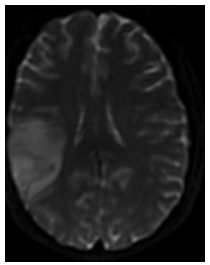
1. In the *Data* module, select the Scene node, and via right-mouse click, select “Insert Transform Node”
2. In the *MRML Node Inspector* below, rename to “Xf0_ManualInit”
3. Move the DWI volume inside the “Xf0_ManualInit” node. Select DWI in the slice view to be visible along with the T2
4. Go to the *Transforms* module. Manually adjust LR rotation and IS translation etc. to roughly align the two volumes.
5. Go to the *Resample Scalar/Vector/DWI Volume* module:
   Input Volume: DWI
   Reference Volume: T2
   Ouput Volume: “Create New Diffusion Weighted Volume”, rename to “DWI_ir”
   Transform Node: “Xf0_ManualInit”.
6. Click “Apply”

DWI -> DTI conversion

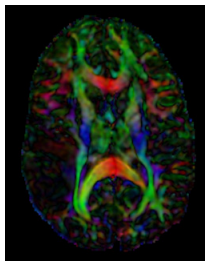
We're now ready to convert the new isotropic DWI into a DTI.
This conversion will produce 3 new volumes:



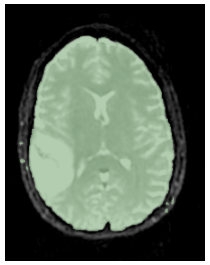
DWI



DTI_base: used as moving image to compute the registration with a T2 reference



DTI:final registration transform will be applied to the tensor to resample it in the new reference space (T2).

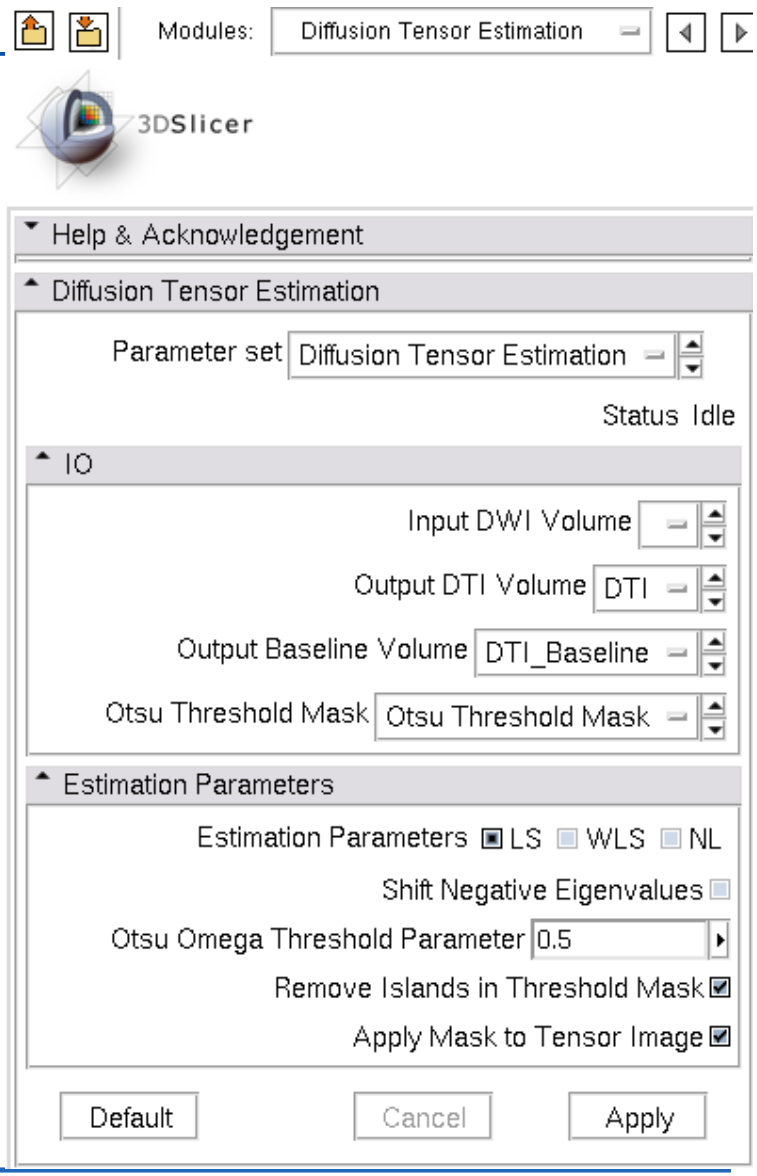


DTI_mask: the mask will be used to guide the automated intensity-based registration of the DTI_baseline. Particularly the nonrigid aspects of the registration to correct for the DTI distortions benefit from the ROI provided by the mask.

Convert DWI -> DTI

1. We next convert the DWI volume into a DTI tensor image that can be used for fiber tracking and other forms of quantifying diffusion.
2. The DTI Estimation module in the Diffusion / Utilities section will perform this task in a single automated step:
    1. Select the DWI image
    2. Create new DTI output image
    3. Create new output baseline volume
    4. Create new Otsu mask volume
    5. Leave Estimation Parameters at defaults
    6. Click Apply

    - The DTI_baseline output will serve as moving image for the registration
    - The Otsu mask image may be useful as mask to focus registration



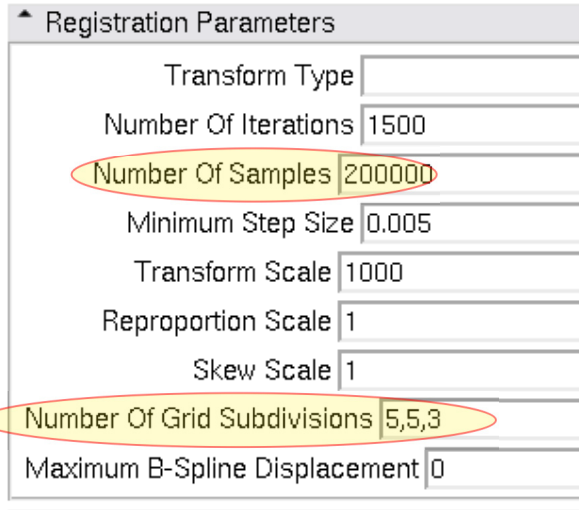
Register DTI baseline to T2

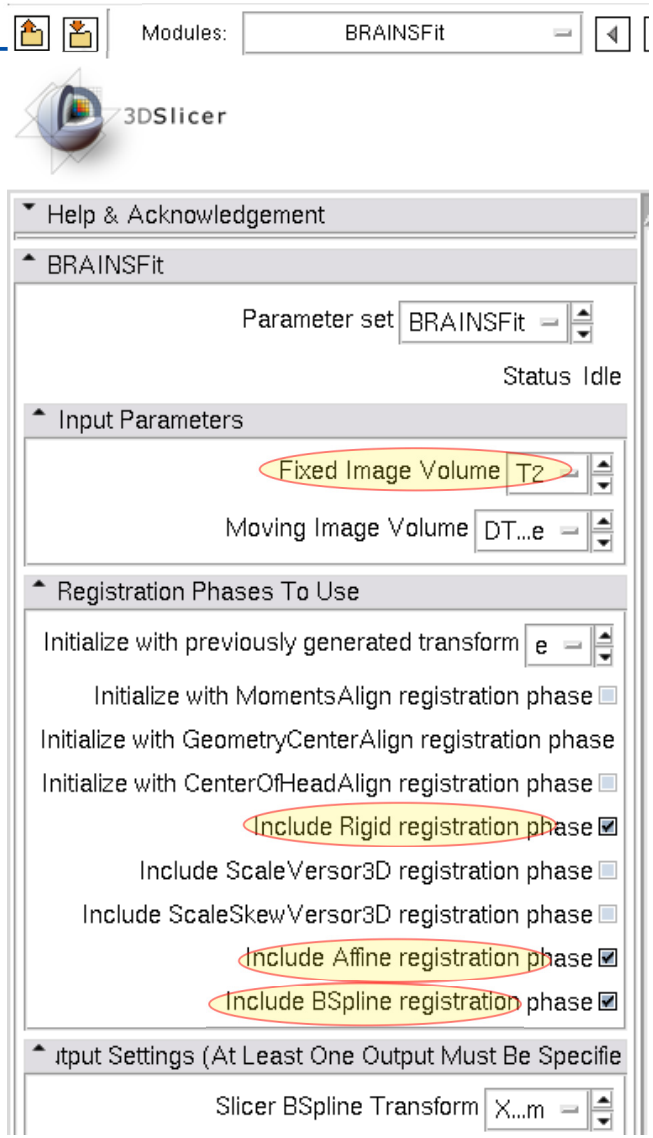
1. Go to the “BrainsFit” module

2. Input:
   Fixed Image: T2
   Moving Image: DTI_baseline

3. Output:
   “Slicer Bspline Tansform”: create new, rename to “Xf1_DTI-T2_unmasked”
   Check boxes for: “rigid”, “affine” + “Bspline” registration

   Registration Parameters as shown below: Changes to defaults highlighted





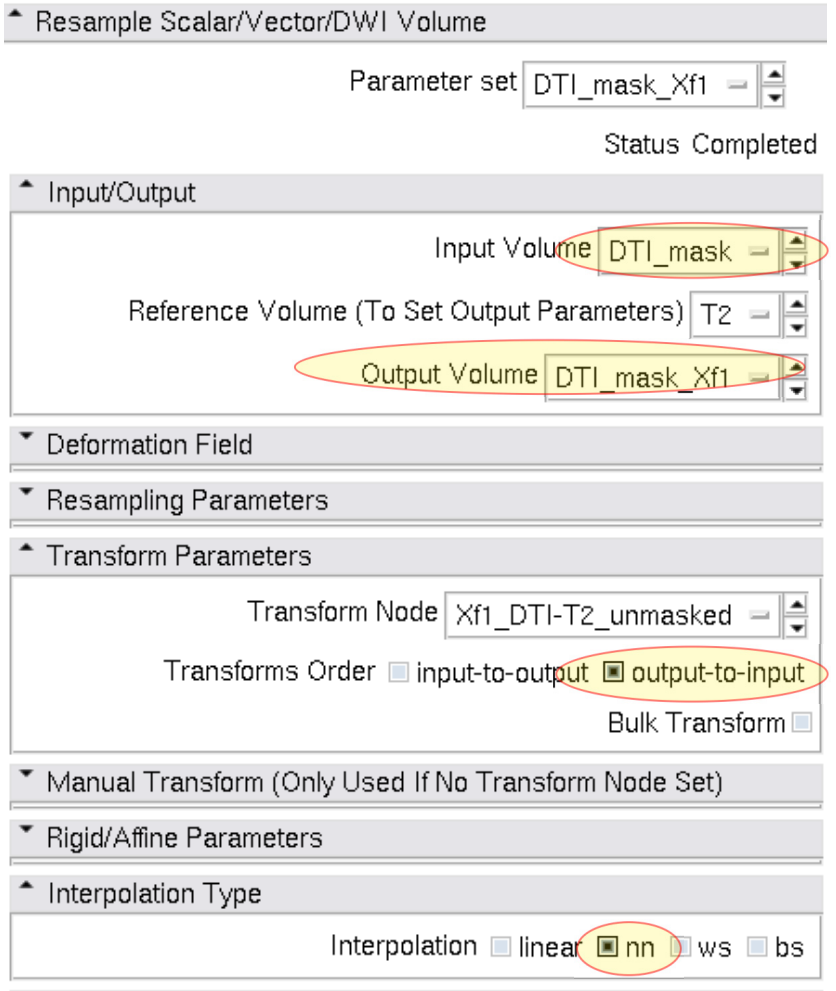
Registration: Masking

- For this scenario a mask of the brain parenchyma is useful and improves registration quality.
- The DTI estimation process produced a mask for the DTI_base image, but we still need a second mask for the T2.
- BRAINSfit requires masks for both the fixed and moving image. To obtain a mask for the fixed image we first perform the same (Affine + Bspline) registration without a mask and use the result transform to resample the DTI_mask volume into the T1 space.
- We can either perform a separate segmentation for the T2 or reuse the DTI_mask by first performing another registration. We'll do the latter here.

Rsample Mask for T2

We apply the obtained transform to the binary mask label file to obtain a new mask for the T2.

1. Go to the *Resample Scalar/Vector/DWI Volume* module:
2. Remember to select “Output-to-input” as the order of transform evaluation and nearest-neighbor (nn) as the interpolation method
3. Click Apply. You should now have a new mask label file to be used in BRAINSfit.



Obtain Mask for T2

This requires :

1. BRAINSfit registration (unmasked), output = Bspline Xform only
2. Resample Scalar/Vector/DWI volume, applied to DTI_mask; output = T2_mask

Register DTI baseline to T2 (masked)

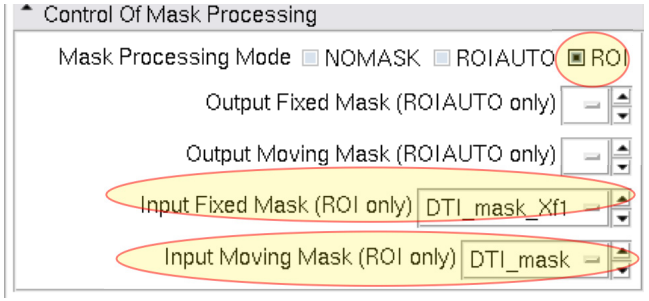
1. We now have the masks to repeat the registration:
   We use the same settings except we add the two mask files:
   Go to the “BrainsFit” module

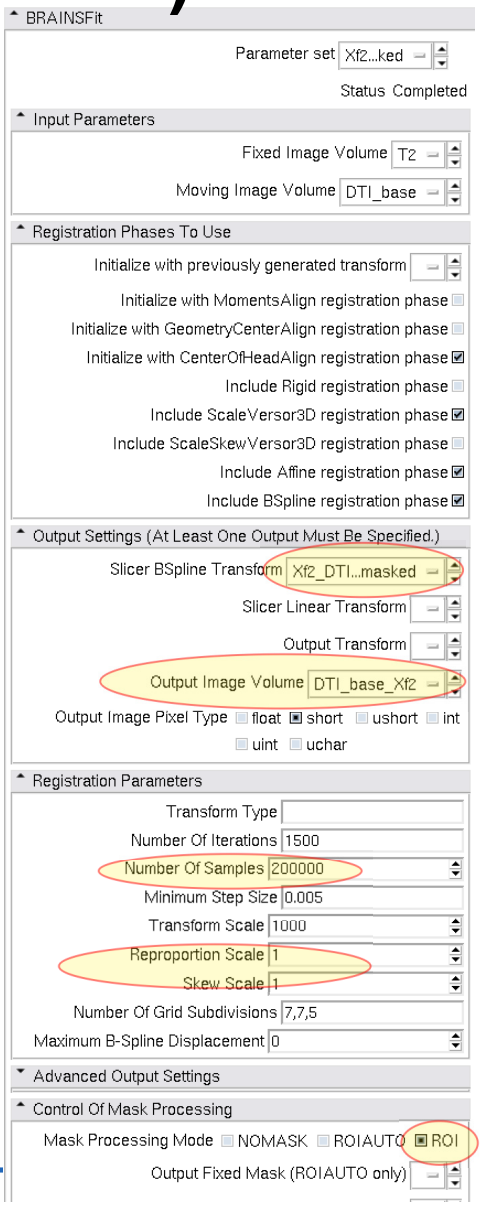
2. Input:
   Fixed Image: T2
   Moving Image: DTI_baseline

3. Mask Processing Tab:
   Check box: Mask Processing Mode: ROI
   Fixed Mask: DTI_mask_Xf1
   Moving Mask: DTI_mask

4. Output:
   “Slicer Bspline Tansform”: create new, rename to “Xf2_DTI-T1_masked”
   “Output Volume”: create new, rename to “DTI_base_Xf2”
   Check boxes for: “rigid”, “affine” + “Bspline” registration

   Registration Parameters as shown below: Changes to defaults highlighted



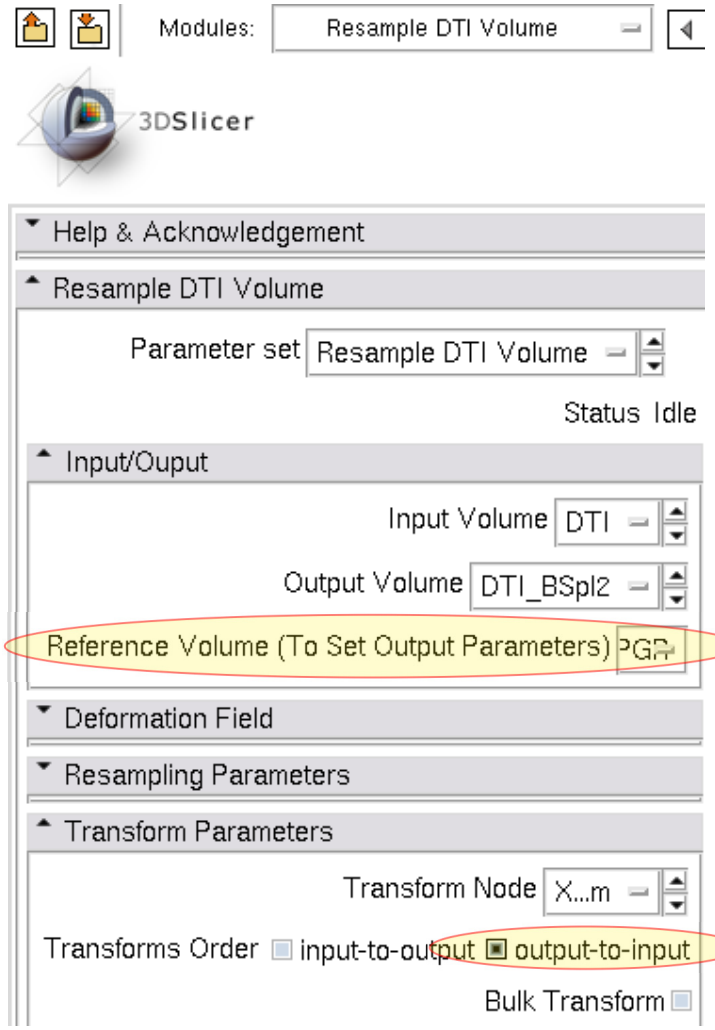


Resample DTI

Last step is to resample the DTI with the new transform (Xf3).

This is done with the *Resample DTI Volume* Module, found in the *Diffusion / Utilities* Set

1. Input image = DTI
   Output Volume = New DTI Volume
   Reference Volume = T2
2. Transform Parameters:
   Transform Node = Xf2_DTI-T2_masked
   Select/check the *output-to-input* box
3. Apply



Results

We have now the DTI in the same orientation and resolution as the T2 reference scan.

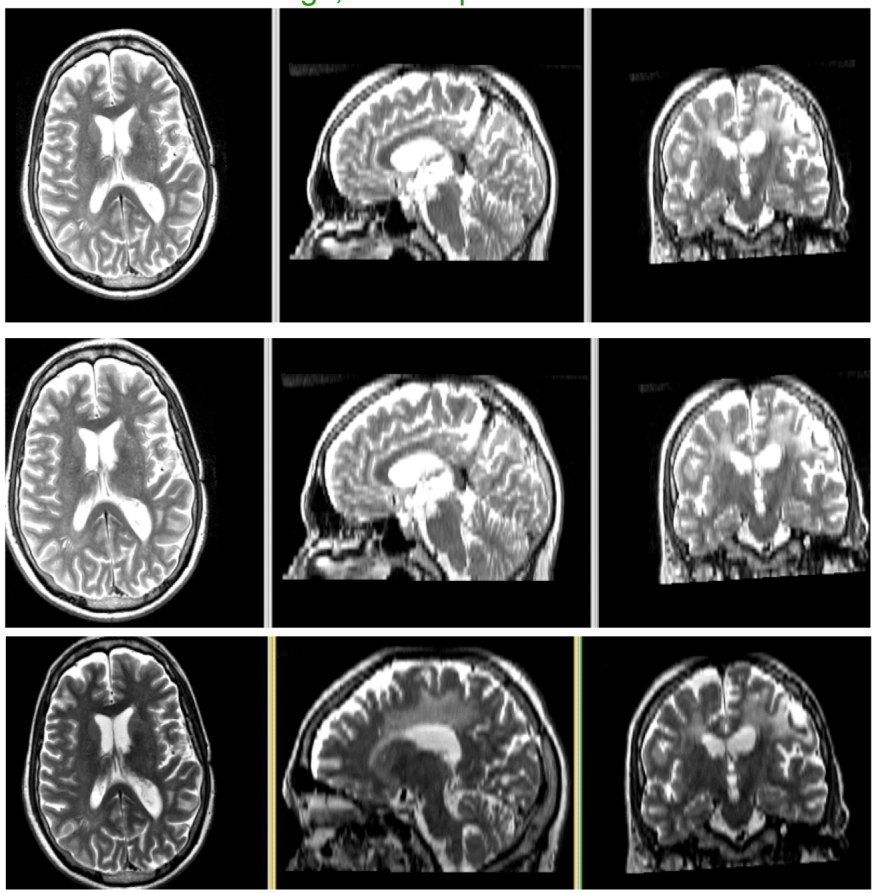
For verification: for the resampled DTI_BSpl2 select “Color Orientation” from the Display tab in the Volumes module, then set fore- and background to the T2 and DTI_Xf2 respectively and drag the fade slider to a halfway position.

animated gif, view in presentation mode

unregistered T2 and DTI_baseline

registered T2 and DTI_baseline

registered T2 and DTI with color orientation view



Acknowledgements

National Alliance for Medical Image Computing
NIH U54EB005149

Neuroimage Analysis Center
NIH P41RR013218 -12S1 (ARRA Suppl)