Slicer3 Tutorial

Registration Library Case 27:

DTI MRI pre-op planning:
align DTI with FLAIR and T1, extensive pathology

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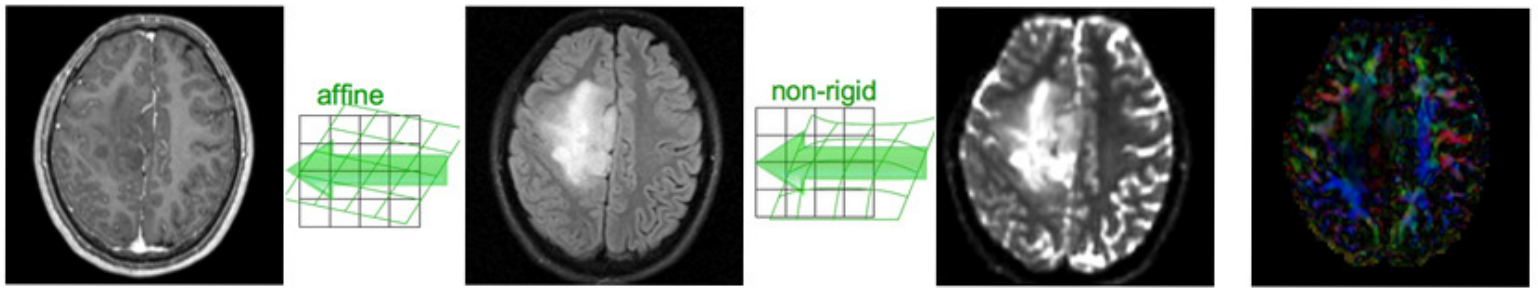
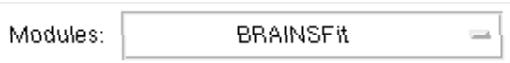
Introduction

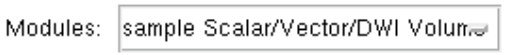
- This is an example dataset of an MRI exam obtained for pre-operative planning. We seek to align the DTI with the structural reference T1 scan to transfer information about critical fiber pathways.
- There is extensive pathology in the right hemisphere and acquisition-related distortion in the DTI data
- The FLAIR provides T2-weighted contrast more similar to the DTI baseline than the T1, which makes it a good target for registration. However it has low axial resolution (4mm thick slices) that make it suboptimal as final space in which to resample the DTI.
- We therefore follow a 2-step approach: 1) we register the FLAIR to the T1 and resample to the same isotropic resolution as present in the T1; 2) we then register the DTI to the resampled FLAIR.



Modules Used

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

  - BRAINSFit Registration Module 

  - Data Module 
  - Resample Scalar/Vector/DWI Volume 

  - Resample DTI Module 

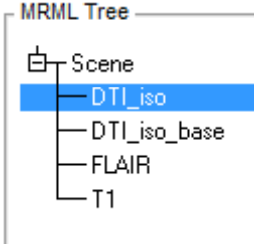
Prerequisites

- Slicer version 3.6.1 or later
- Example Dataset: download and extract the dataset for this tutorial: Slicer3_BRAINSFITRegistration.zip, which should contain this tutorial, all original and some intermediate solution data files.
- Tutorials to complete first (optional):
  - Slicer3Minute Tutorial
  - Loading and Viewing Data
  - DTI tutorial

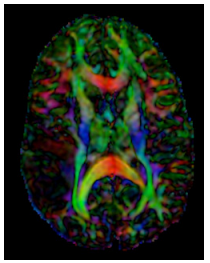
Load Patient Data

- Open the .mrml scene RegLib_C27_Short_Data.mrml using **File -> LoadScene**

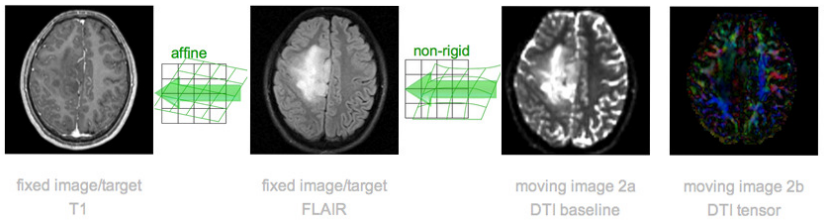
- Input data:
  - T1 = structural T1 MRI
  - FLAIR = T2 MRI
  - DTI_iso_base = DTI baseline
  - DTI_iso = DTI tensor image

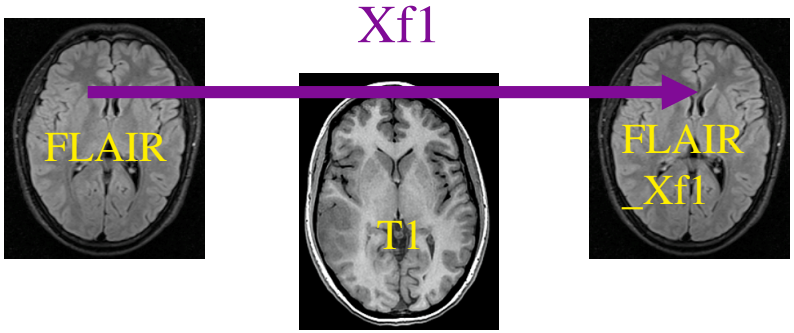


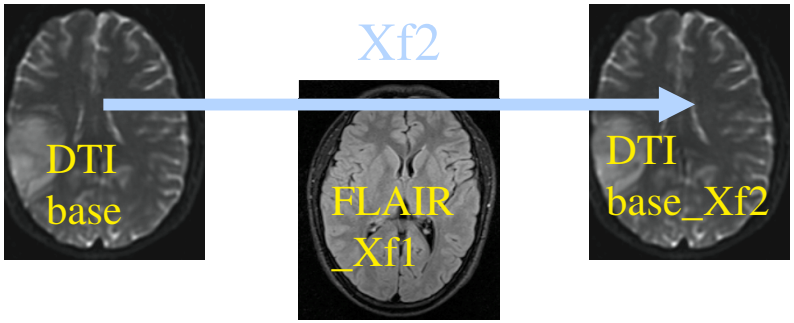
- To view the DTI tensor image:
  - Select DTI_iso in the Volumes module
  - Select Scalar Mode: Color Orientation

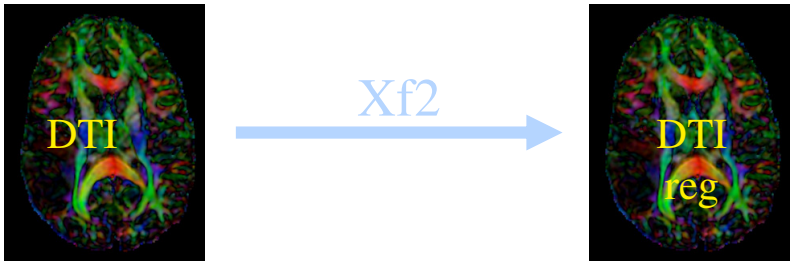


Registration Strategy









1.Register the FLAIR scan to the T1 (affine)

2.Register the DTI_baseline to the registered FLAIR

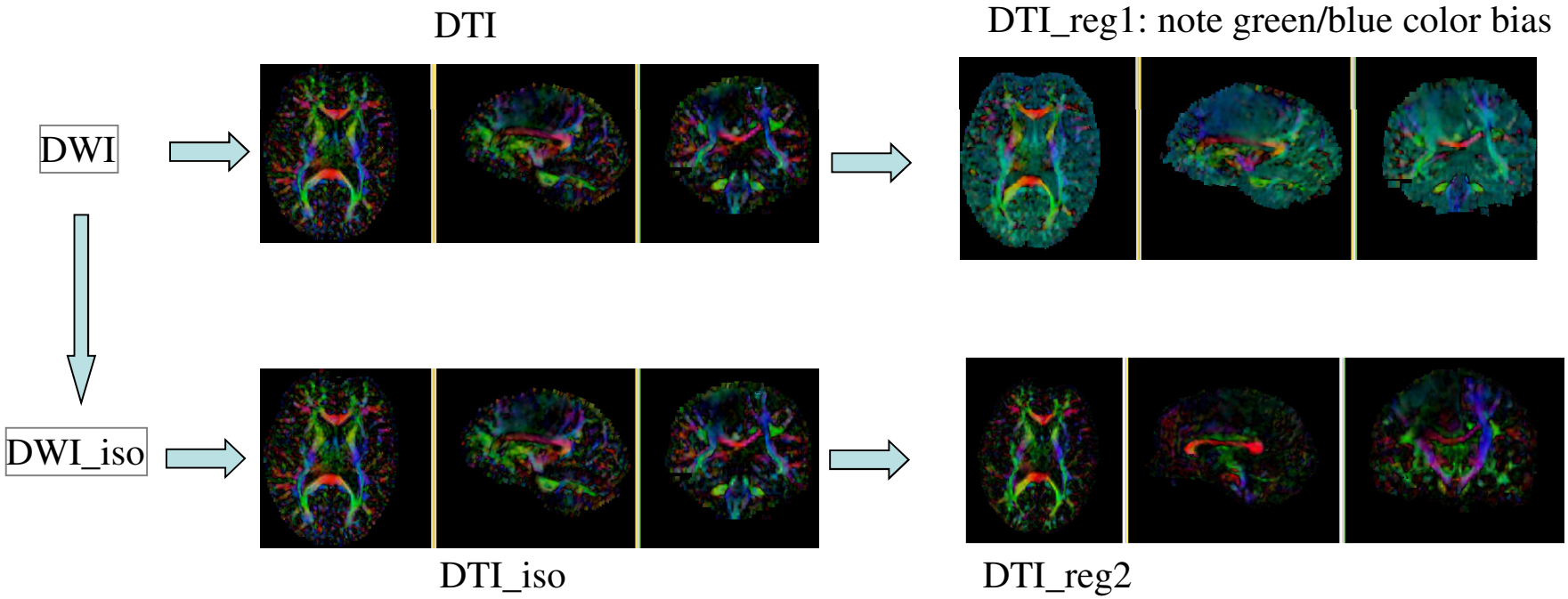
3.Apply the second transform to the DTI volume.

The reason for these 2 steps is that best registration quality and robustness is achieved when image contrast and/or resolution are similar. A registration of the DTI_baseline to the T1 is a large step in both image contrast and resolution / FOV and likely to fail

We register to the T2 **after** it is aligned with the T1. Registering to the original T2 and then moving to the T1 would require concatenating transforms in a form not currently supported, or alternatively would require additional resampling which would reduce DTI image quality.

Resolution & Anisotropy Issues

- The original DWI image has a voxel size of 1.96 x 1.96 x 3 mm. The DTI estimation and subsequent rotation of the tensor data can lead to strong interpolation artifacts: in this case directionality in the z-direction (inferior-superior) will “blur” across slices and lead to a systematic bias/offset in the final resample DTI image (DTI_reg1).
- It is therefore recommended to first resample the DWI to an isotropic resolution similar to the target space, and then perform DTI estimation and registration (DTI_reg2).



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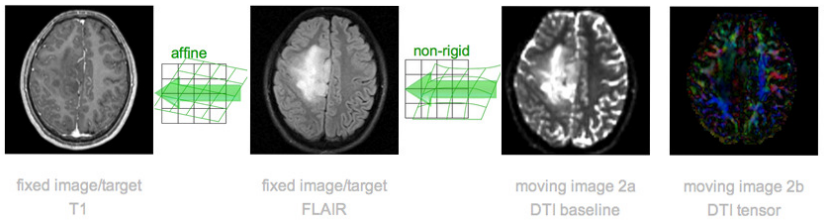

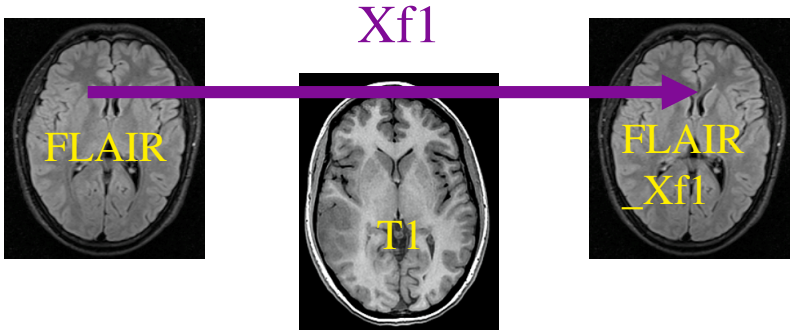

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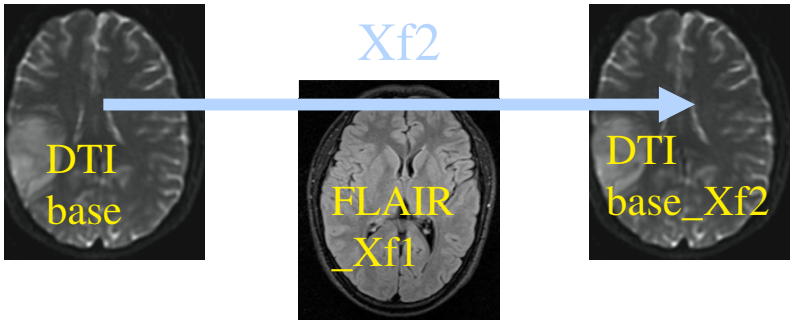
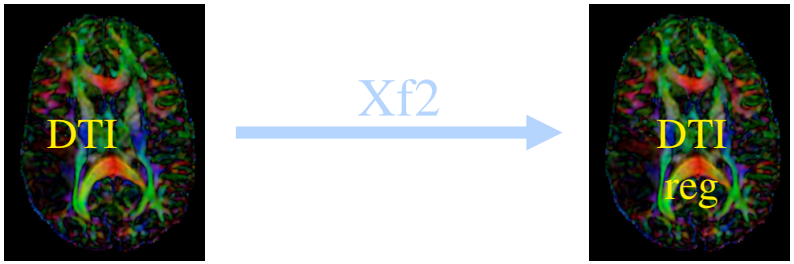




Register T2 (FLAIR) -> T1

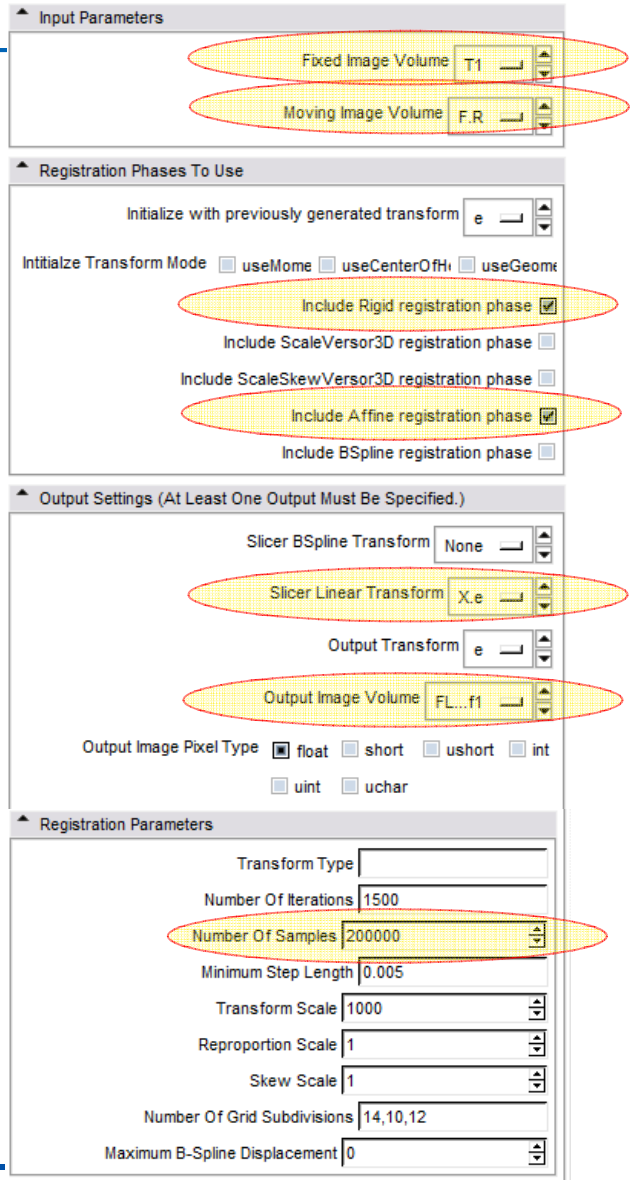
1. Go to the “BrainsFit” module (under Registration tab)

2. Input:
   Fixed Image: T1
   Moving Image: FLAIR

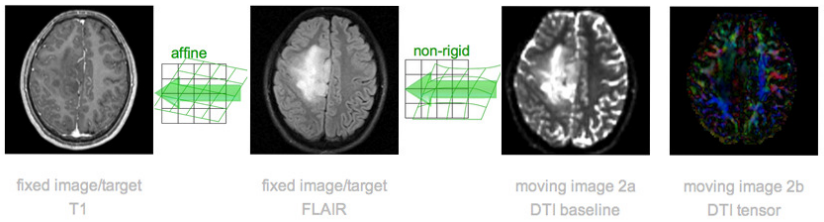
3. Output
   Check boxes for: “rigid”, “affine” registration phases
   Slicer Linear Transform: Create new, rename to “Xf1_FLAIR-T1_Affine”
   Output Volume: Create new, rename to “FLAIR_Xf1”
   Registration Parameters: All defaults, except:
   Number of Samples 200,000

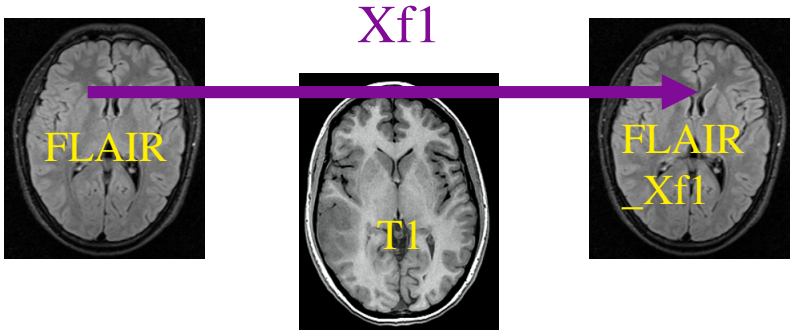
4. Evaluate alignment: T1 and FLAIR_Xf1
   Choose T1 as the background, FLAIR_Xf1 as the foreground, and toggle the fade slider

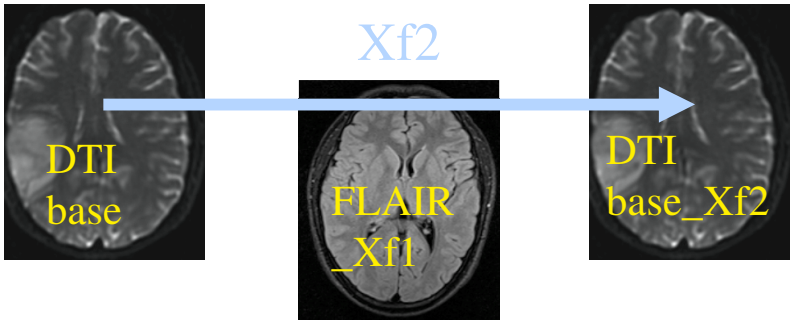
5. Evaluate change: FLAIR and FLAIR_Xf1
   Choose FLAIR as the background, FLAIR_Xf1 as the foreground, and toggle the fade slider
   Note FLAIR_Xf1 is resampled to the same resolution as T1

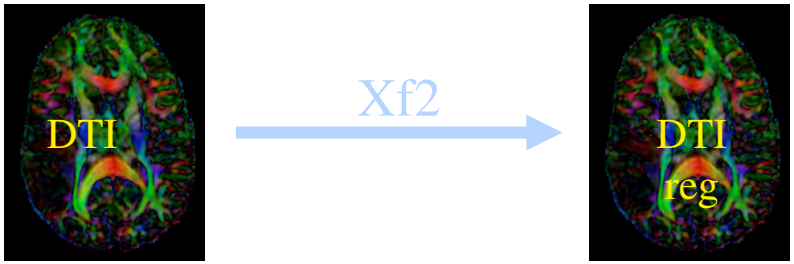


Registration Strategy









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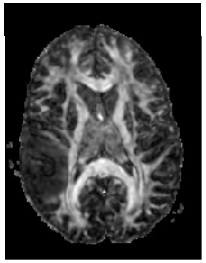
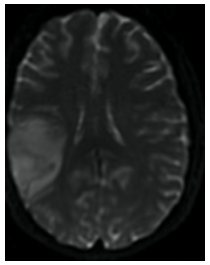
DWI -> DTI conversion (done for you)

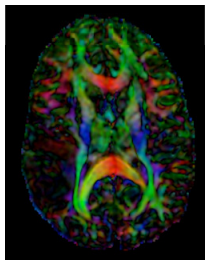
The anisotropic DWI has been previously resampled to isotropic resolution. It was then converted to a DTI tensor image that can be used for fiber tracking and other forms of quantifying diffusion.
This conversion produced 3 new volumes:



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 (unused): the mask could 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.

Register DTI baseline to FLAIR

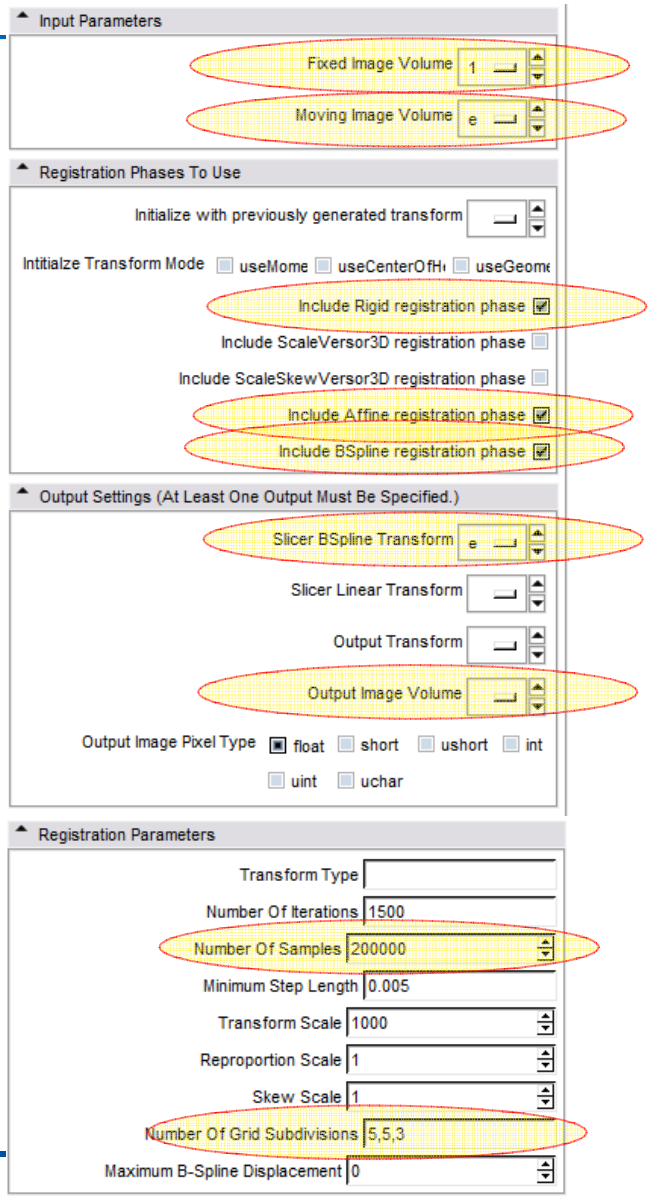
1. Go to the “BrainsFit” module

2. Input:
   Fixed Image: FLAIR_Xf1
   Moving Image: DTI_iso_base

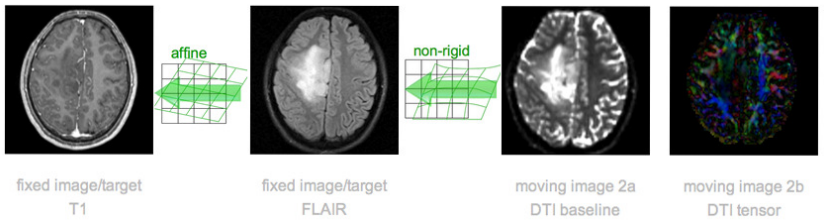
3. Output:
   Check boxes for: “rigid”, “affine” + “Bspline” registration phases
   Slicer Bspline Transform: Create new, rename to
   “Xf2_DTI-FLAIR_Bspline”
   Output Image Volume: Create new, rename to DTI_iso_base_Xf2
   Registration Parameters: All default except
   Number of Samples 200,000 ,
   Number of Grid Subdivisions 5,5,3

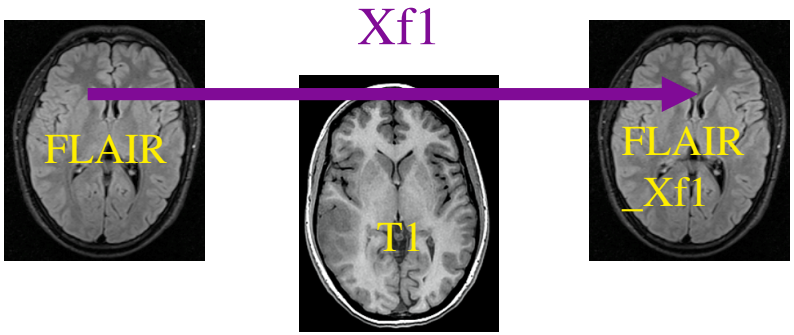
4. Evaluate alignment: FLAIR_Xf1 and DTI_iso_base_Xf2
   Choose FLAIR_Xf1 as the background, DTI_iso_base_Xf2 as the foreground, and toggle the fade slider

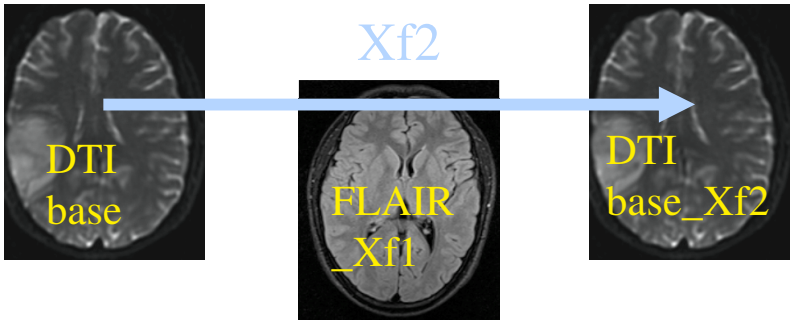
5. Evaluate change: DTI_iso_base and DTI_iso_base_Xf2
   Choose DTI_iso_base as the background, DTI_iso_base_Xf2 as the foreground, and toggle the fade slider

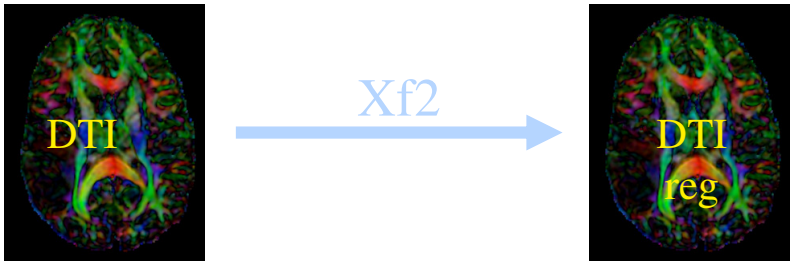


Registration Strategy









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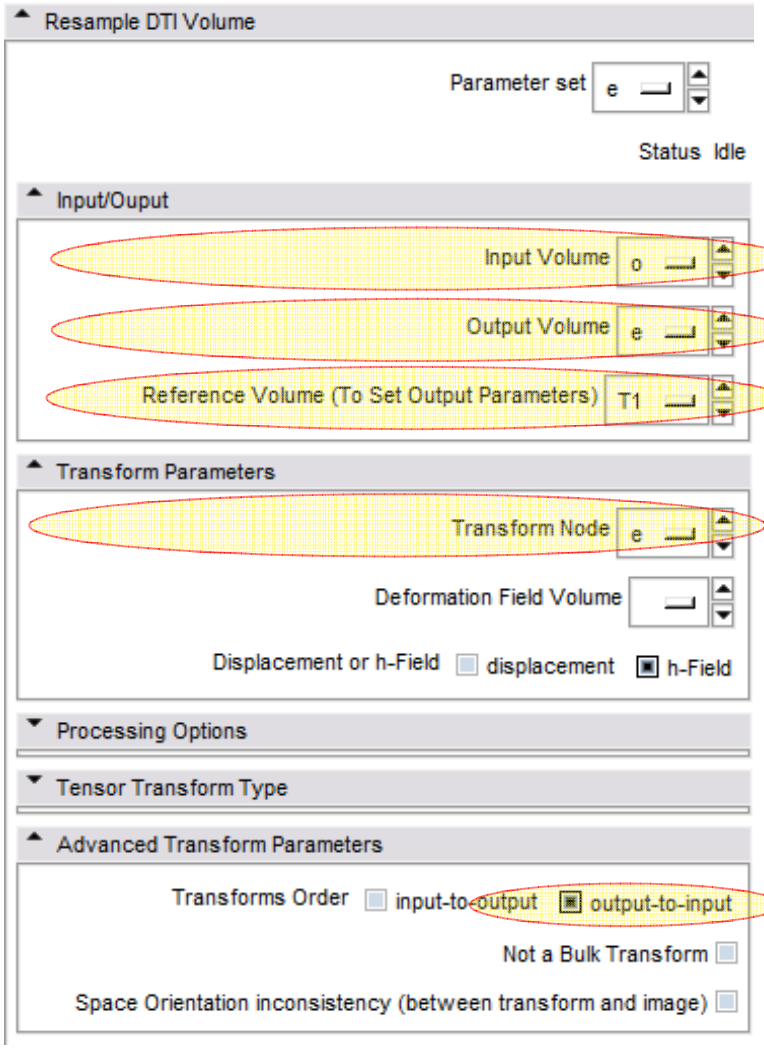
Resample DTI

The last step is to resample the DTI with the new transform (Xf2).

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

1. Go to the “Resample DTI Volume” module
2. Input/Output:
   Input Image: DTI_iso
   Output Volume: Create new DTI Volume, rename to DTI_iso_Xf2
   Reference Volume: T1
3. Transform Parameters:
   Transform Node: Xf2_DTI-FLAIR_Bspline
   Under Advanced Transform Parameters: Check output-to-input
4. Evaluate change: DTI_iso and DTI_iso_Xf2
   Open the Volumes module, for DTI_iso_Xf2, choose
   Scalar Mode: Color Alignment
   Choose None as the background
   Toggle between DTI_iso and DTI_iso_Xf2 as the foreground

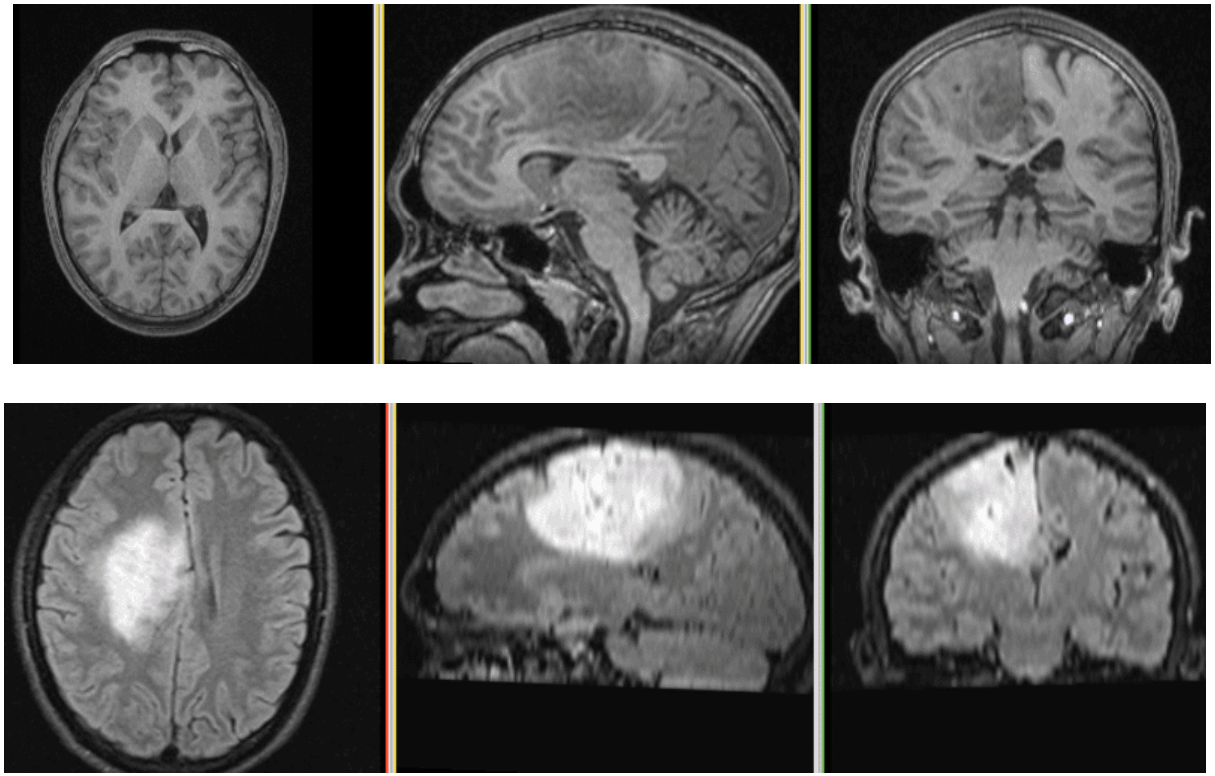


Results

We have now the DTI in the same orientation and resolution as the T1 reference scan.

For verification of the final registration results:
Choose T1 as the foreground, DTI_iso_Xf2 as the background, and toggle the fade slide

animated gifs, view in presentation mode



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