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.
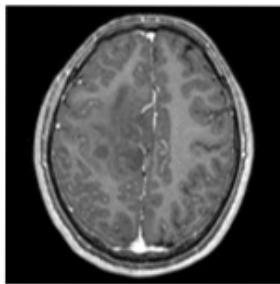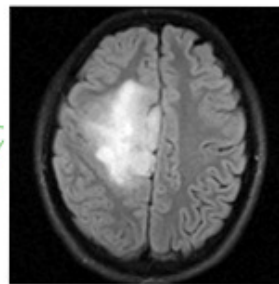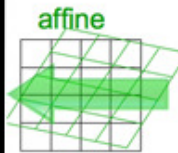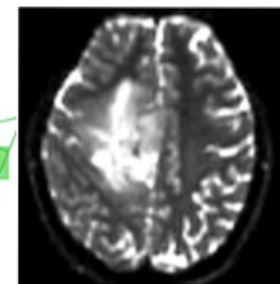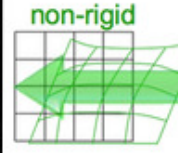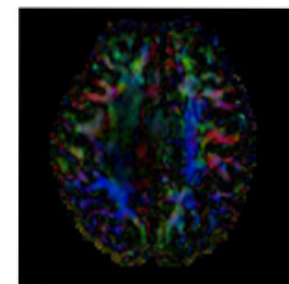

| fixed image/target
T1 | affine | fixed image/target
FLAIR | non-rigid | moving image 2a
DTI baseline | moving image 2b
DTI tensor |

Modules Used

- ## To accomplish this task we will use the following modules:

  – Volumes Module

  – Diffusion Tensor Estimation Module

  Modules: Diffusion Tensor Estimation

  – BRAINSFit Registration Module

  Modules: BRAINSFit

  – Data Module

  – Resample Scalar/Vector/DWI Volume

  Modules: sample Scalar/Vector/DWI Volume

  – Resample DTI Module

  Modules: Resample DTI Volume

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

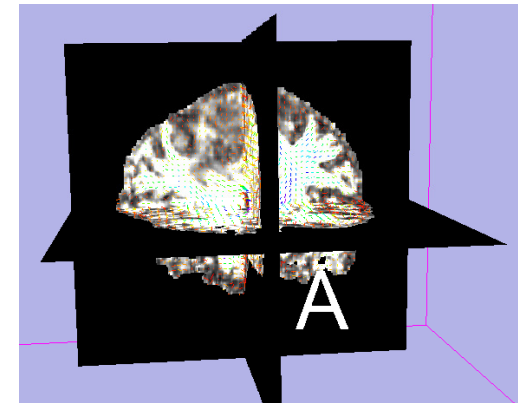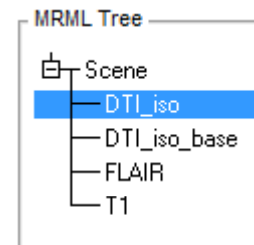 – Loading and Viewing Data

  – DTI tutorial

Load Patient Data

- Open the .mrml scene RegLib_C27_Short_Data.mrml using **File -> LoadScene**
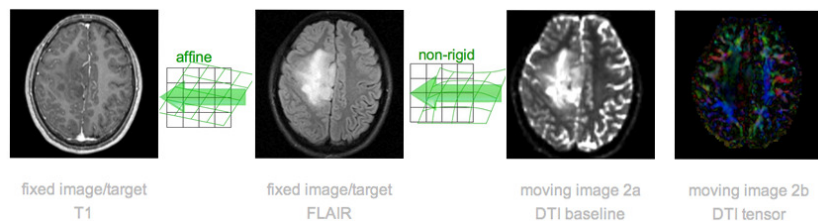
- Input data:
  - T1 = structural T1 MRI
  - FLAIR = T2 MRI
  - DTI_iso_base = DTI baseline
  - DTI_iso = DTI tensor image

- To view DTI tensor glyphs – **Volumes module**:
  - Select DTI_iso and toggle "Glyphs on Slices Display" Visibility Red/Yellow/Green
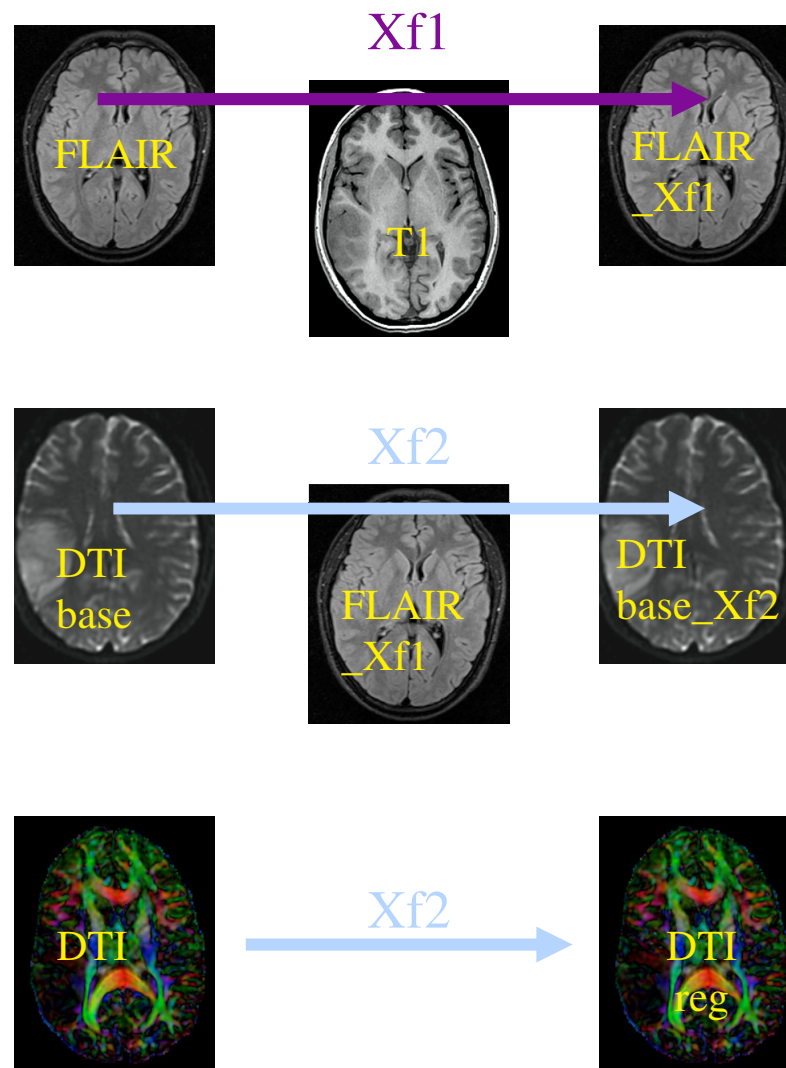
Registration Strategy

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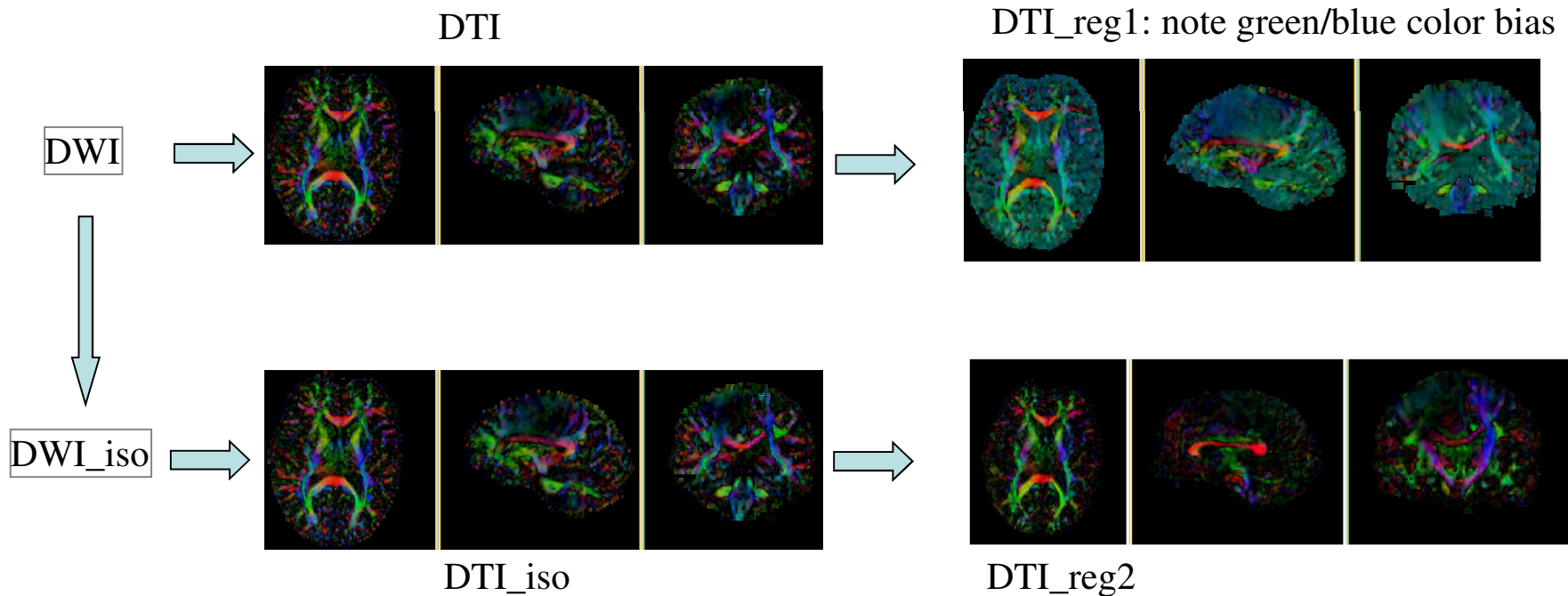
We register to the T2 **after** it is aligned with the T1. Registering to the original T2 and then moving to the T1 would require concatenating transforms in a form not currently supported, or alternatively would require additional resampling which would reduce DTI image quality.

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).

DTI

DTI_reg1: note green/blue color bias

DWI

DWI_iso

DTI_iso

DTI_reg2

Registration Strategy

fixed image/target T1 — fixed image/target FLAIR — moving image 2a DTI baseline — moving image 2b DTI tensor

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

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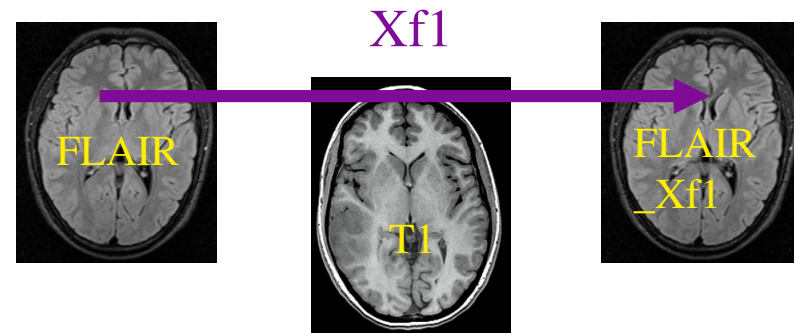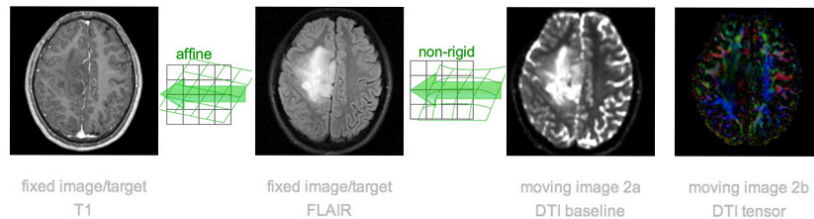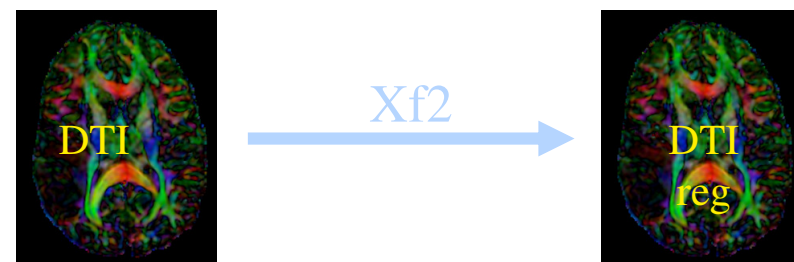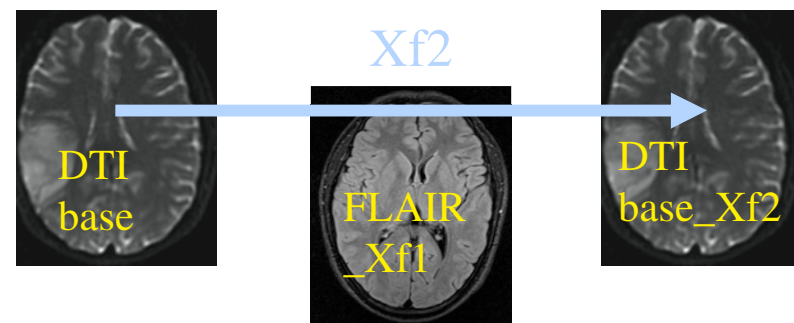

Xf1 — FLAIR — T1 — FLAIR_Xf1

Xf2 — DTI base — FLAIR_Xf1 — DTI base_Xf2

Xf2 — DTI — DTI reg

Register T2 (FLAIR) -> T1

1. Go to the "BrainsFit" module

2. Create new parameter set

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

4. 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"
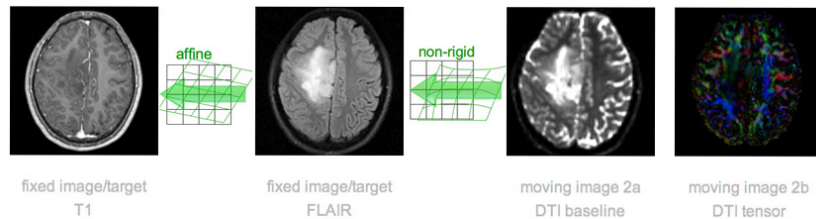   Registration Parameters:
   All defaults except:
   Number of Samples 200,000

Registration Strategy

fixed image/target — T1 (affine)
fixed image/target — FLAIR (non-rigid)
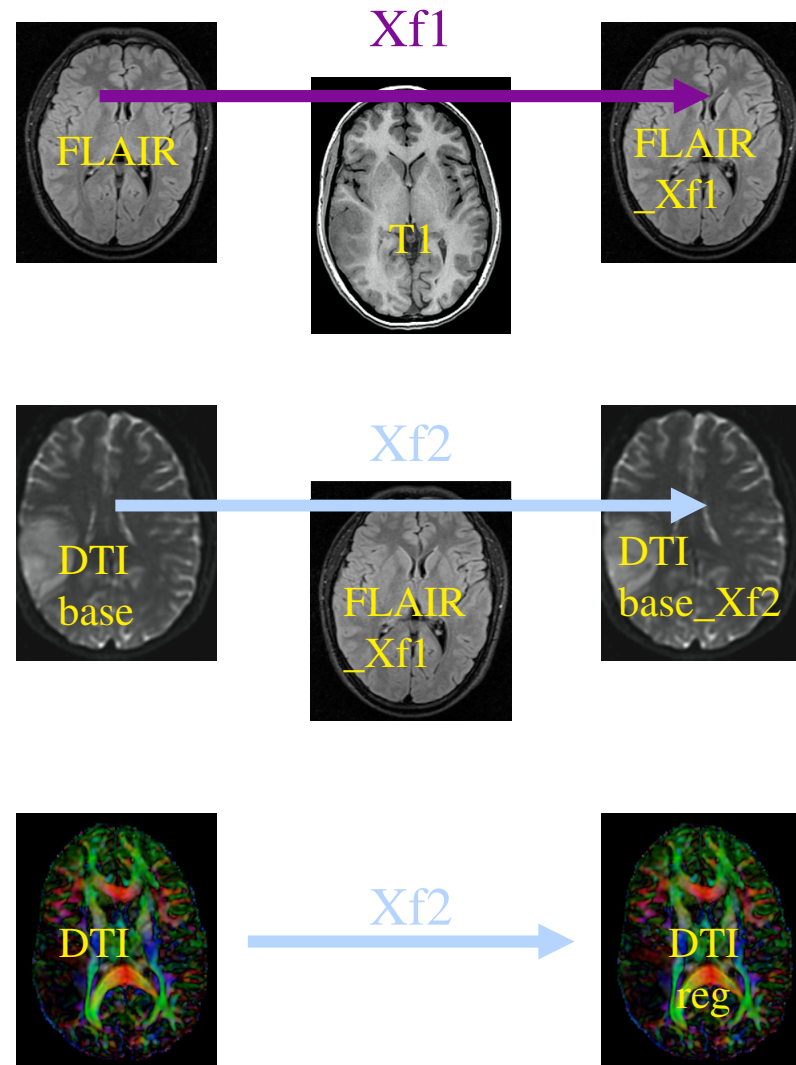moving image 2a — DTI baseline
moving image 2b — DTI tensor

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.

Xf1 — FLAIR → T1 → FLAIR_Xf1

Xf2 — DTI base → FLAIR_Xf1 → DTI base_Xf2
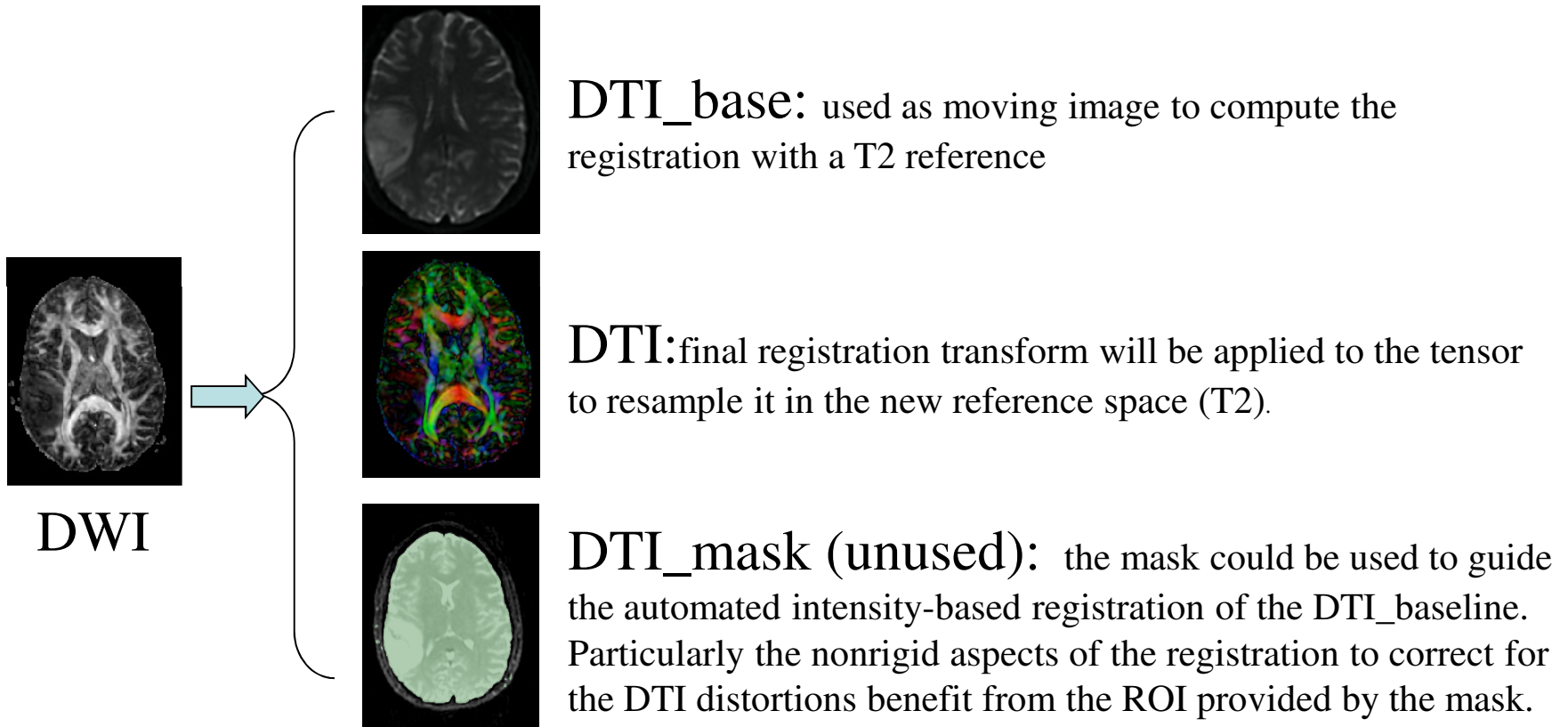
Xf2 — DTI → DTI reg

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:

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.
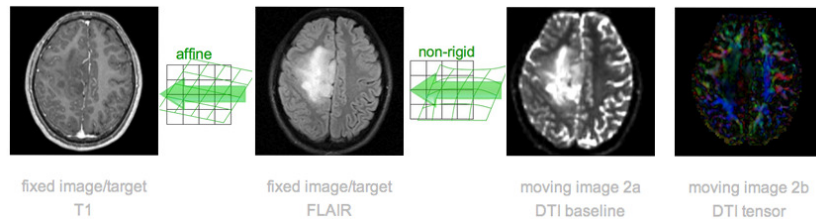
DWI

Register DTI baseline to FLAIR

1. Go to the "BrainsFit" module

2. Create new parameter set

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

4. Output:
   Check boxes for: "rigid", "affine" + "Bspline" registration phases
   "Slicer Bspline Transform": create new, rename to
   "Xf2_DTI-FLAIR_Bspline"
   Registration Parameters:
   all defaults except:
   Number of Samples 200,000 ,
   Number of Grid Subdivisions 5,5,3

Input Parameters

Fixed Image Volume: 1

Moving Image Volume: e

Registration Phases To Use

Initialize with previously generated transform

Intitialze Transform Mode: ☐ useMome ☐ useCenterOfH ☐ useGeome

Include Rigid registration phase ☑
Include ScaleVersor3D registration phase ☐
Include ScaleSkewVersor3D registration phase ☐
Include Affine registration phase ☑
Include BSpline registration phase ☑

Output Settings (At Least One Output Must Be Specified.)

Slicer BSpline Transform: e
Slicer Linear Transform
Output Transform
Output Image Volume

Output Image Pixel Type: ◉ float ☐ short ☐ ushort ☐ int
☐ uint ☐ uchar

Registration Parameters

Transform Type
Number Of Iterations: 1500
Number Of Samples: 200000
Minimum Step Length: 0.005
Transform Scale: 1000
Reproportion Scale: 1
Skew Scale: 1
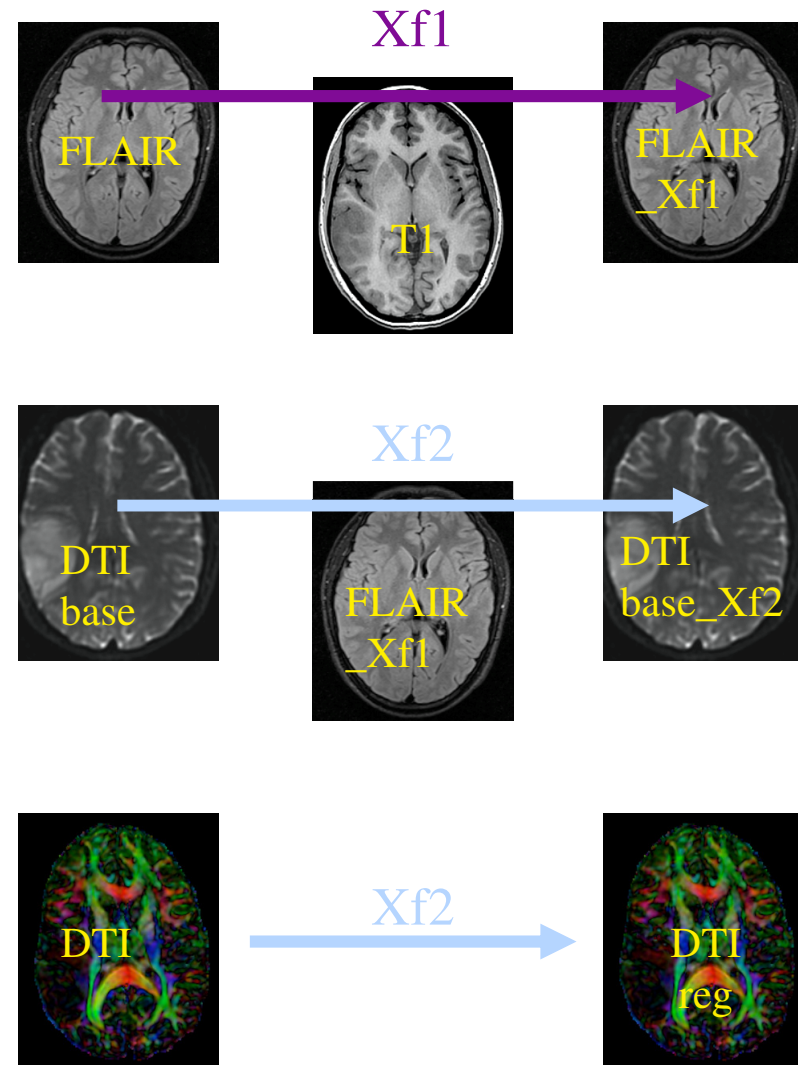Number Of Grid Subdivisions: 5,5,3
Maximum B-Spline Displacement: 0

Registration Strategy

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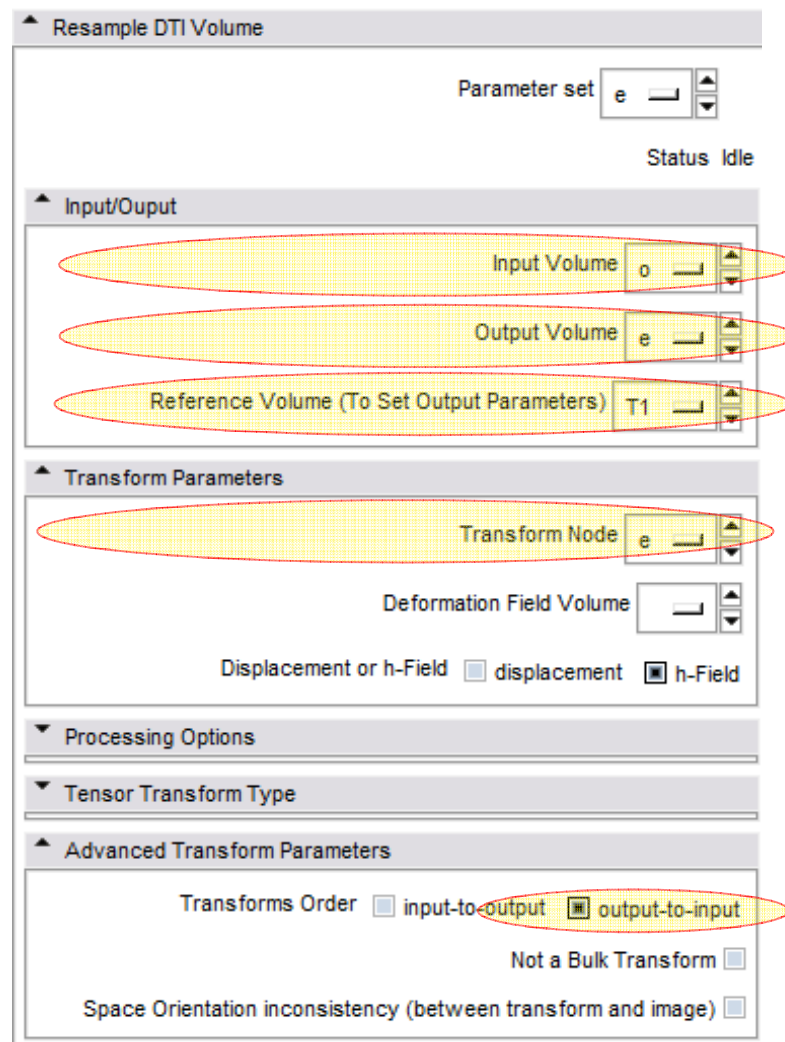
Resample DTI

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. Create new parameter set

2. Input image = DTI_iso
   Output Volume = Create new DTI Volume, rename to DTI_Xf2
   Reference Volume = T1

3. Transform Parameters:
   Transform Node = Xf2_DTI-FLAIR_BSpline
   Select/check the *output-to-input* box under Advanced Transform Parameters

4. Apply

Results

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

For verification: for the resampled DTI_Xf2 select "Color Orientation" from the Display tab in the Volumes module, then set fore- and background to the T1 and DTI_Xf2 respectively and drag the fade slider to a halfway position.

animated gifs, view in presentation mode
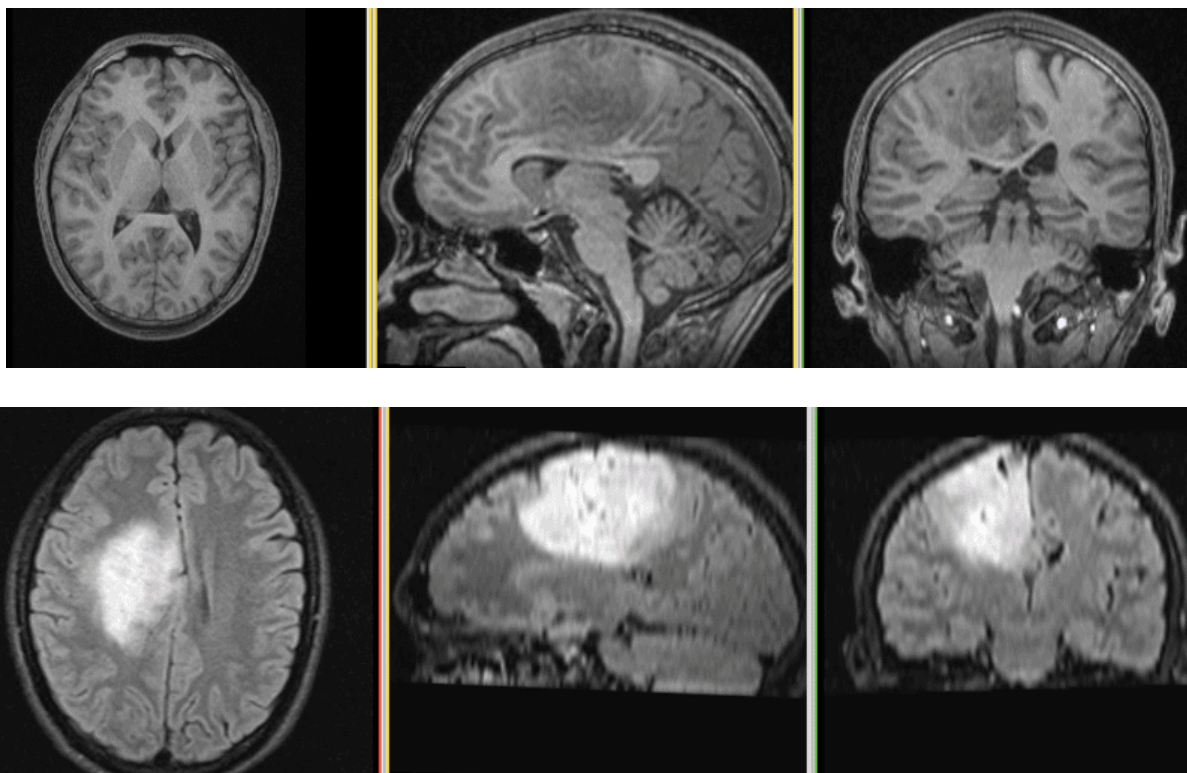
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