



# **Slicer3 Tutorial**

## **Registration Library Case 27:**

**DTI MRI pre-op planning:**

**align DTI with FLAIR and T1, extensive pathology**

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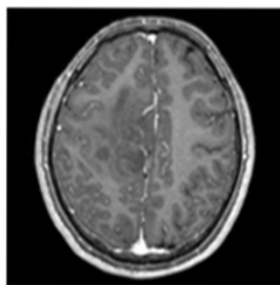
June 2011

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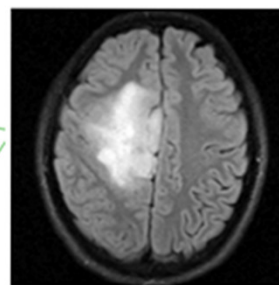
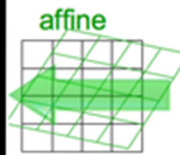


# Introduction

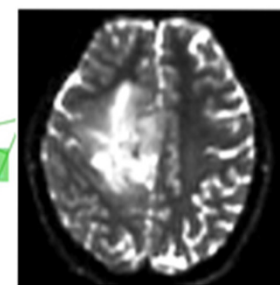
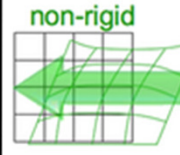
- This is an example dataset of an MRI exam obtained for pre-operative planning. We seek to align the DTI with the structural reference T1 scan to transfer information about critical fiber pathways.
- There is extensive pathology in the right hemisphere and acquisition-related distortion in the DTI
- 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.



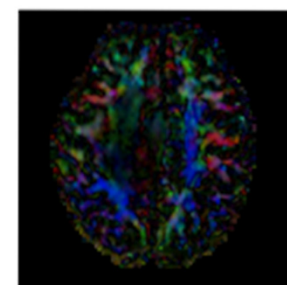
fixed image/target  
T1



fixed image/target  
FLAIR



moving image 2a  
DTI baseline



moving image 2b  
DTI tensor



## Modules Used

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

- Volumes Module



- Diffusion Tensor Estimation Module

Modules:

- BRAINSFit Registration Module

Modules:

- Data Module



- Resample Scalar/Vector/DWI Volume

Modules:

- Resample DTI Module

Modules:



# Prerequisites

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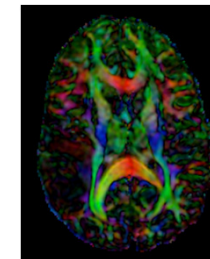
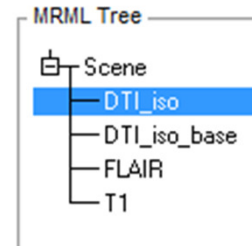
- Slicer version 3.6.1 or later
- **Example Dataset:** download and extract the dataset for this tutorial: Slicer3\_BRAINSFITRegistration.zip, which should contain this tutorial, all original and some intermediate solution data files.
- Tutorials to complete first (optional):
  - Slicer3Minute Tutorial
  - Loading and Viewing Data
  - DTI tutorial



# Load Patient Data

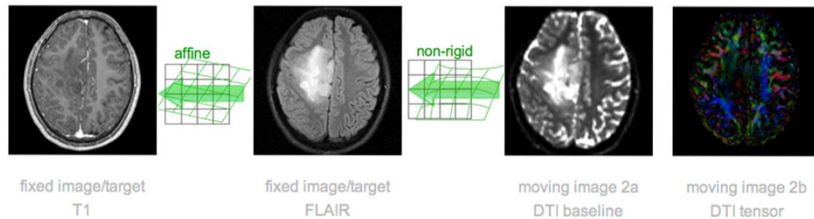
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- Open the .mrml scene RegLib\_C27\_Short\_Data.mrml using **File -> LoadScene**
- Input data:
  - T1 = structural T1 MRI
  - FLAIR = T2 MRI
  - DTI\_iso\_base = DTI baseline
  - DTI\_iso = DTI tensor image
- View the images in the 3D Slice viewers
- To view the DTI tensor image:
  - Select DTI\_iso in the Volumes module
  - Select Scalar Mode: Color Orientation





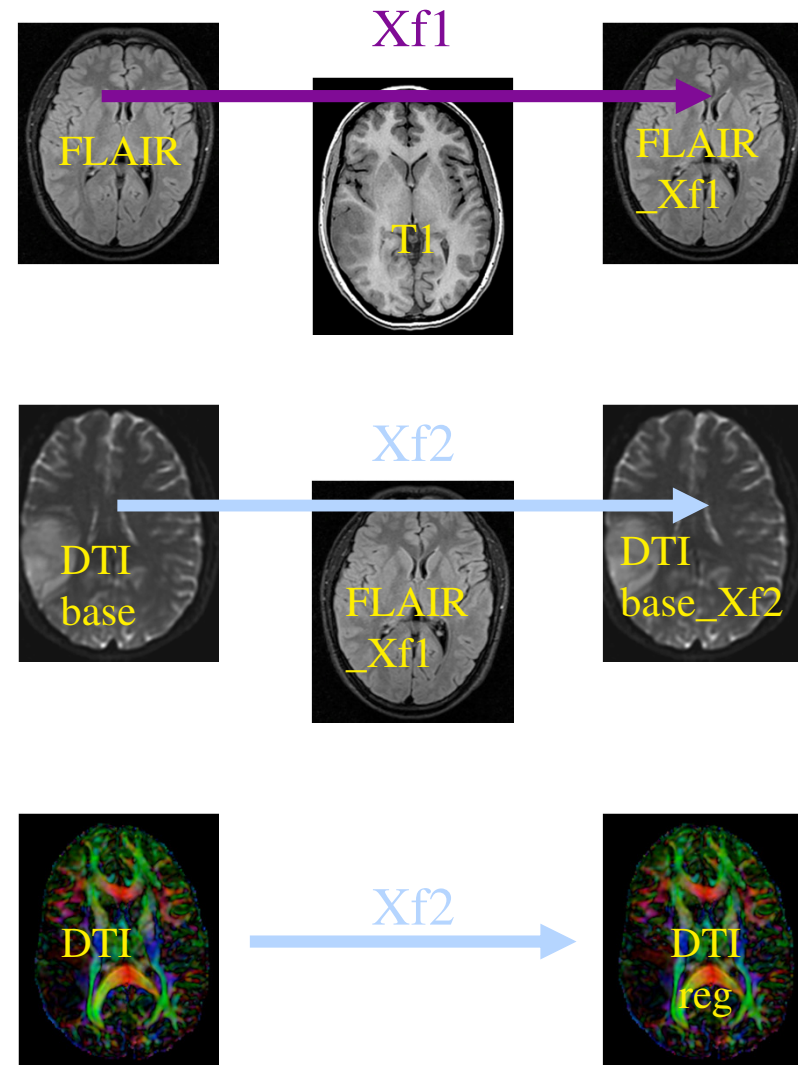
# Registration Strategy



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.





## Resample T1 for speed and memory

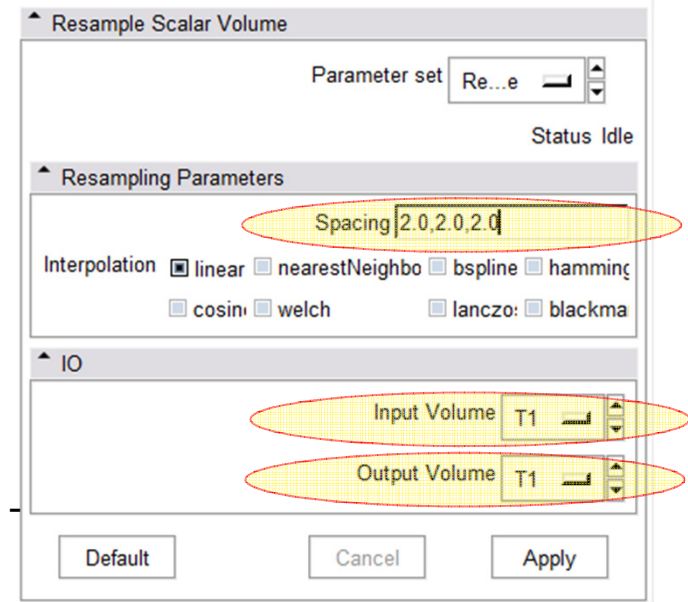
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- To view image information:
  - Open the **Volumes** module
  - Select Active Volume T1
  - Open Info tab to see dimensions, spacing, origin, scan order, number of scalars, scalar type
- Original T1 resolution is 0.98 x 0.98 x 1.0
- The registered DTI image will be resampled to match the T1 image
- For tutorial speed and to prevent memory allocation problems, we will resample the T1 to 2.0 x 2.0 x 2.0



# Resample T1

1. Go to the “Resample Scalar Volume” module (under Filtering tab)
2. Resampling Parameters:  
Spacing: 2.0, 2.0, 2.0
3. I/O  
Input Volume: T1  
Output Volume: Create new volume, rename “T1-resampled”
4. Apply
5. To verify: Check the Volumes module Info tab for T1-resampled
6. Delete original T1: Open Data module  
Right click on T1, and select Delete Node

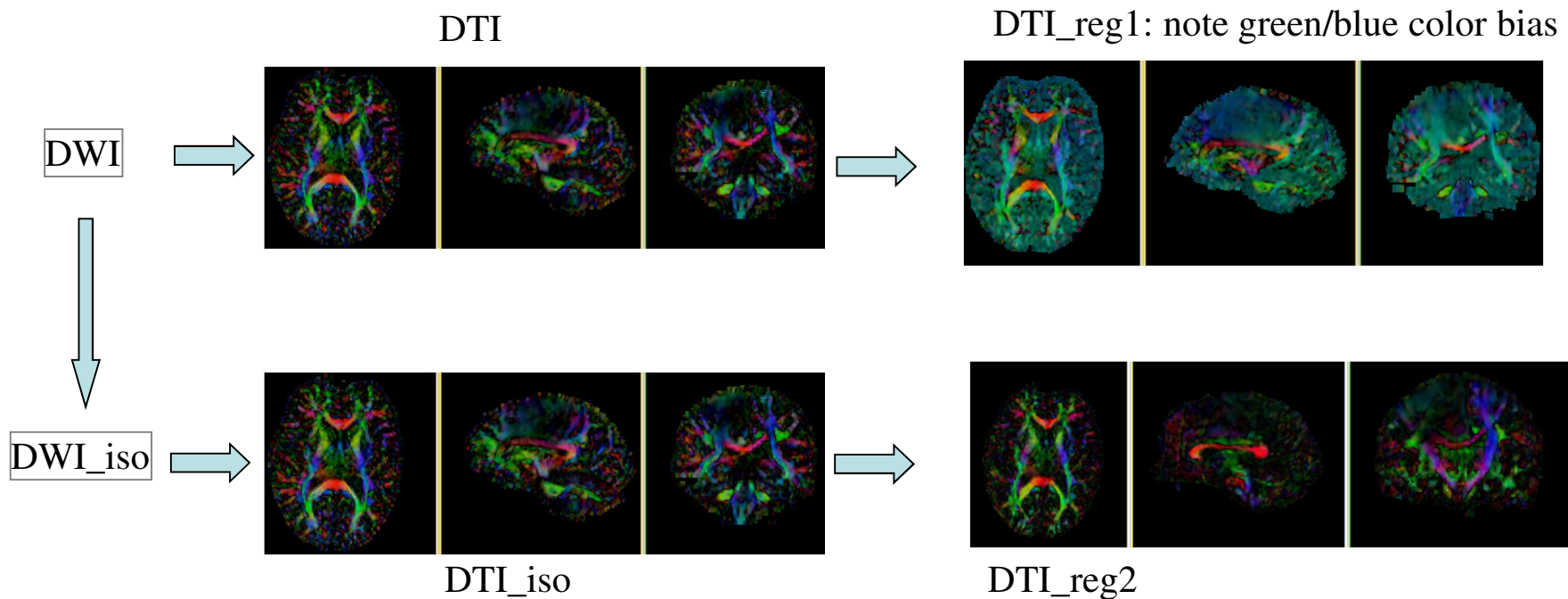






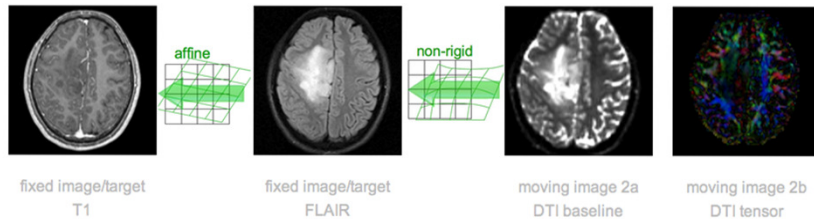
# Resolution & Anisotropy Issues

- 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).





# Registration Strategy



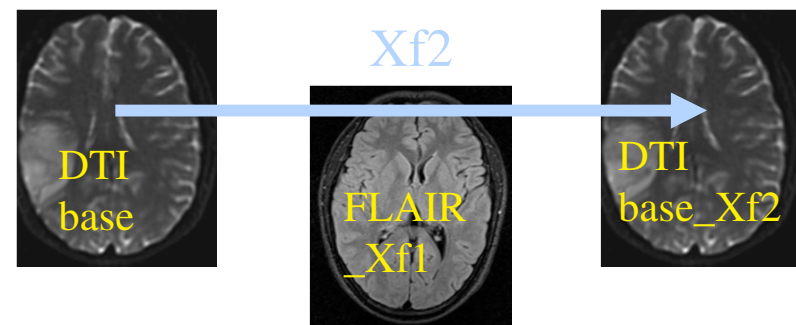
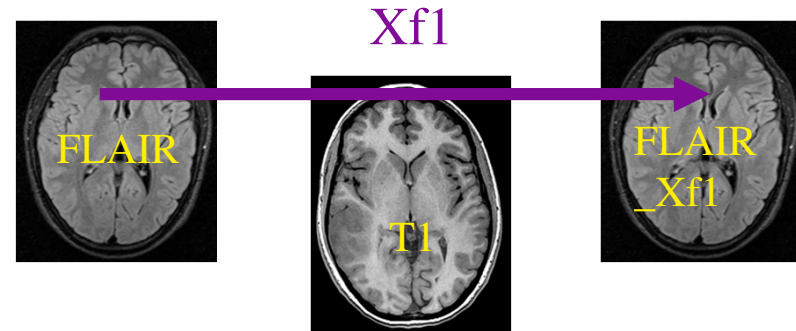
**1. Register the FLAIR scan to the T1 (affine)**

**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.





# Register T2 (FLAIR) -> T1

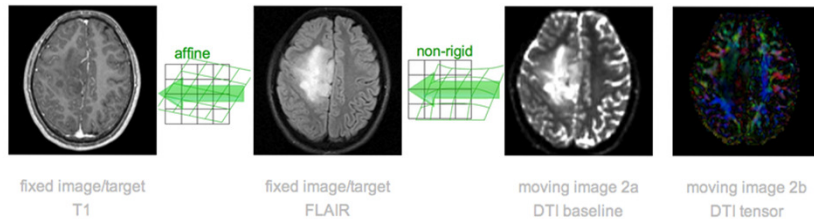
1. Go to the “BrainsFit” module (under Registration tab)
2. Input:  
Fixed Image: T1-resampled  
Moving Image: FLAIR
3. Output  
Check boxes for: “rigid”, “affine” registration phases  
Slicer Linear Transform: Create new, rename to “Xf1\_FLAIR-T1\_Affine”  
Output Volume: Create new, rename to “FLAIR\_Xf1”  
Registration Parameters: All defaults, except:  
Number of Samples 200,000
4. Apply, and wait until Status Completed
5. Evaluate alignment: T1-resampled and FLAIR\_Xf1  
Choose T1-resampled as the background, FLAIR\_Xf1 as the foreground,  
and toggle the fade slider
6. 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-resampled

The screenshot shows the BrainsFit registration module interface with several settings highlighted in red ovals:

- Input Parameters:**
  - Fixed Image Volume: T1
  - Moving Image Volume: FLAIR
- Registration Phases To Use:**
  - Initialize with previously generated transform: e
  - Initialize Transform Mode: useNone, useCenterOfH, useGeom
  - 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: None
  - Slicer Linear Transform: Xf1
  - Output Transform: e
  - Output Image Volume: FLAIR\_Xf1
  - Output Image Pixel Type:  float,  short,  ushort,  int,  uint,  uchar
- Registration Parameters:**
  - Transform Type: [empty]
  - 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: 14,10,12
  - Maximum B-Spline Displacement: 0



# Registration Strategy



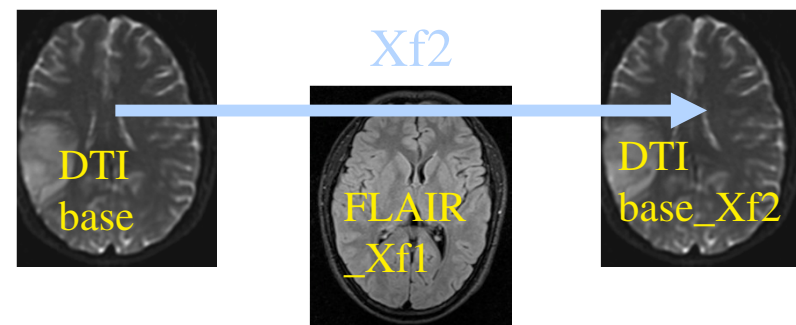
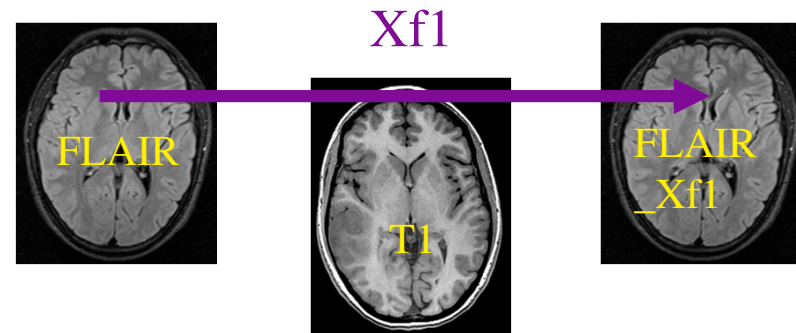
1. Register the FLAIR scan to the T1 (affine)

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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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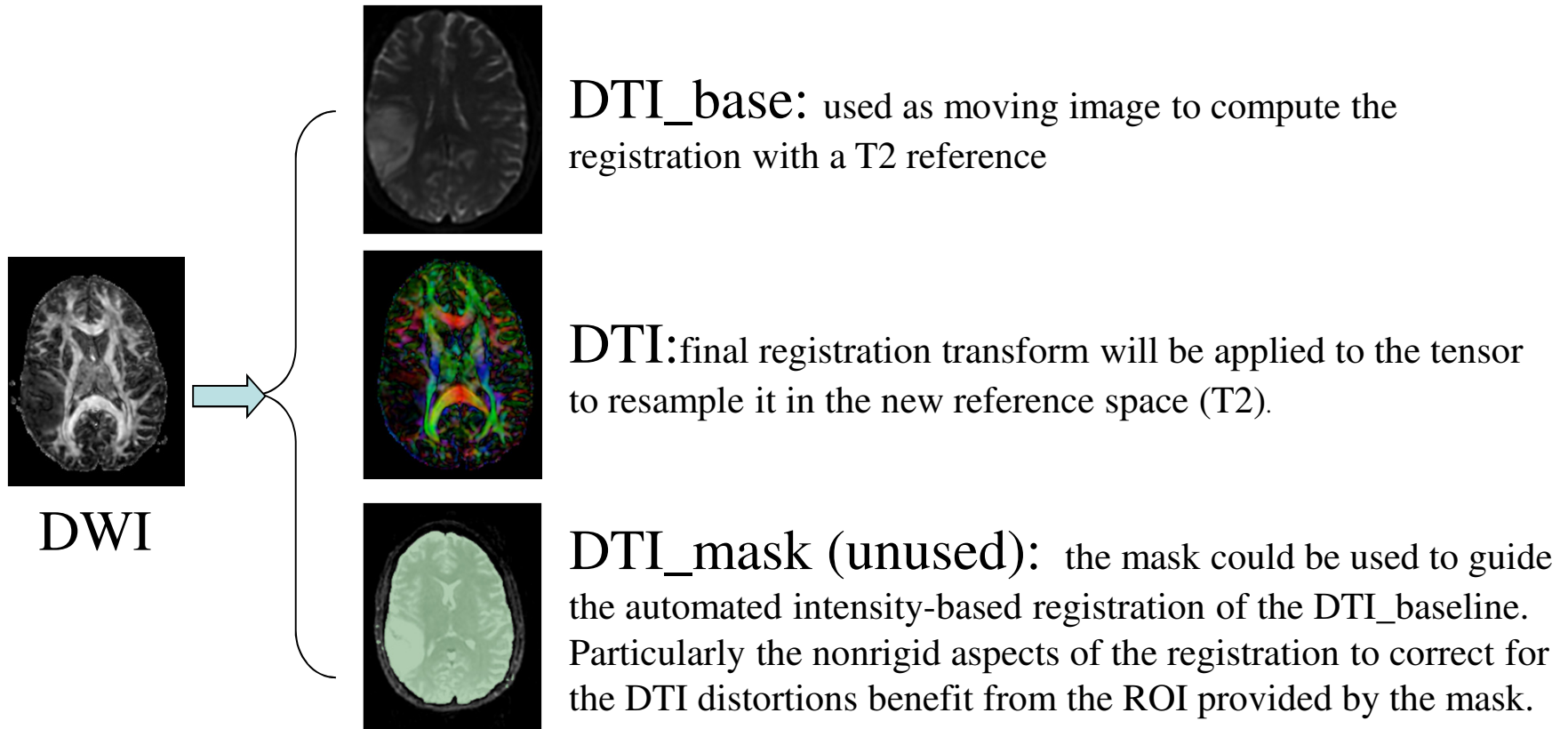




# DWI -> DTI conversion (done for you)

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:





# Register DTI baseline to FLAIR

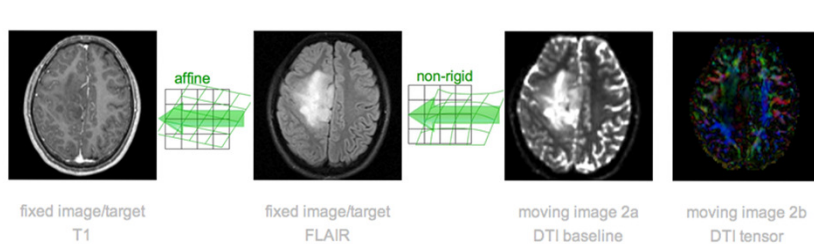
1. Go to the “BrainsFit” module
2. Input:  
Fixed Image: FLAIR\_Xf1  
Moving Image: DTI\_iso\_base
3. Output:  
Check boxes for: “rigid”, “affine” + “B-spline” registration phases  
Slicer B-spline Transform: Create new, rename to “Xf2\_DTI-FLAIR\_Bspline”  
Output Image Volume: Create new, rename to DTI\_iso\_base\_Xf2  
Registration Parameters: All default except  
Number of Samples 200,000 ,  
Number of Grid Subdivisions 5,5,3
4. Apply, and wait until Status Completed
5. 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
6. 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

The screenshot shows the BrainsFit registration module interface with several settings highlighted in red ovals:

- Input Parameters:**
  - Fixed Image Volume: 1
  - Moving Image Volume: e
- Registration Phases To Use:**
  - Initialize with previously generated transform: [dropdown]
  - Initialize Transform Mode:  useMome  useCenterOfH  useGeomt
  - Include Rigid registration phase:
  - Include ScaleVersor3D registration phase:
  - Include ScaleSkewVersor3D registration phase:
  - Include Affine registration phase:
  - Include B-spline registration phase:
- Output Settings (At Least One Output Must Be Specified.):**
  - Slicer B-spline Transform: e
  - Slicer Linear Transform: [dropdown]
  - Output Transform: [dropdown]
  - Output Image Volume: [dropdown]
  - Output Image Pixel Type:  float  short  ushort  int  uint  uchar
- Registration Parameters:**
  - Transform Type: [dropdown]
  - 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



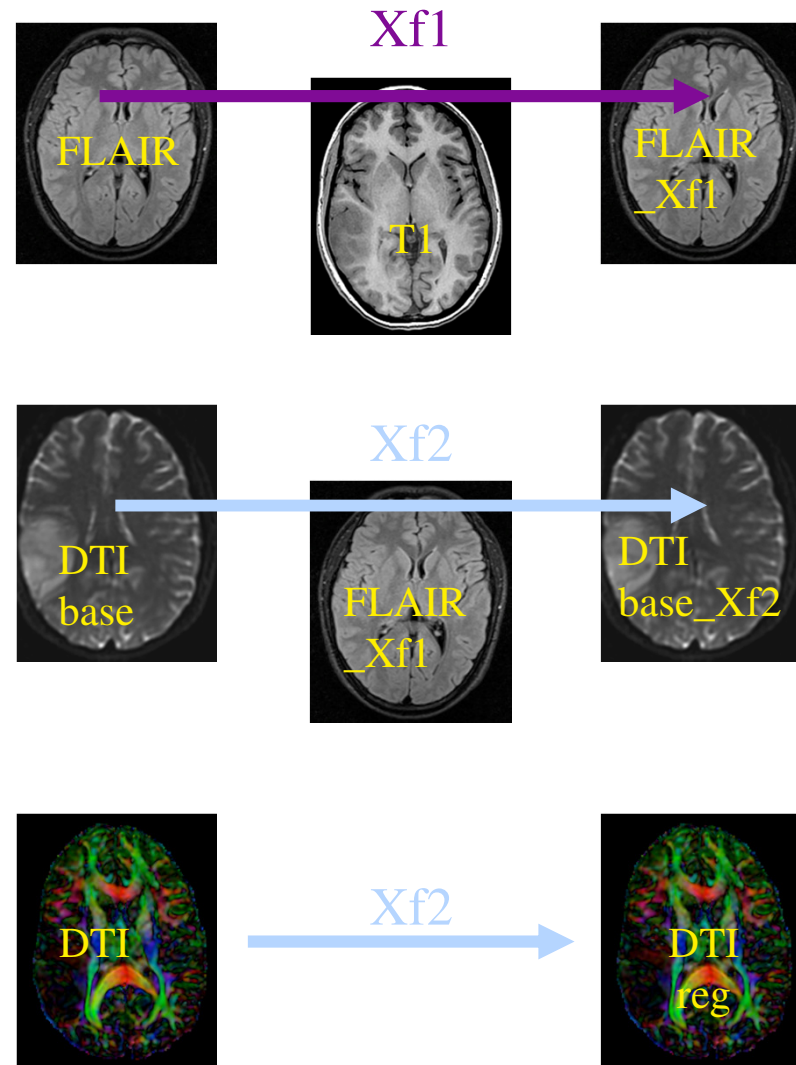
# Registration Strategy



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





# Resample DTI

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

1. Go to the “Resample DTI Volume” module (under Diffusion / Utilities tab)
2. Input/Output:  
Input Image: DTI\_iso  
Output Volume: Create new DTI Volume, rename to DTI\_iso\_Xf2  
Reference Volume: T1-resampled
3. Apply, and wait until Status Completed
4. Transform Parameters:  
Transform Node: Xf2\_DTI-FLAIR\_Bspline  
Under Advanced Transform Parameters: Check output-to-input
5. 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

Resample DTI Volume

Parameter set e

Status Idle

Input/Output

Input Volume o

Output Volume e

Reference Volume (To Set Output Parameters) T1

Transform Parameters

Transform Node e

Deformation Field Volume

Displacement or h-Field  displacement  h-Field

Processing Options

Tensor Transform Type

Advanced Transform Parameters

Transforms Order  input-to-output  output-to-input

Not a Bulk Transform

Space Orientation inconsistency (between transform and image)





# Results

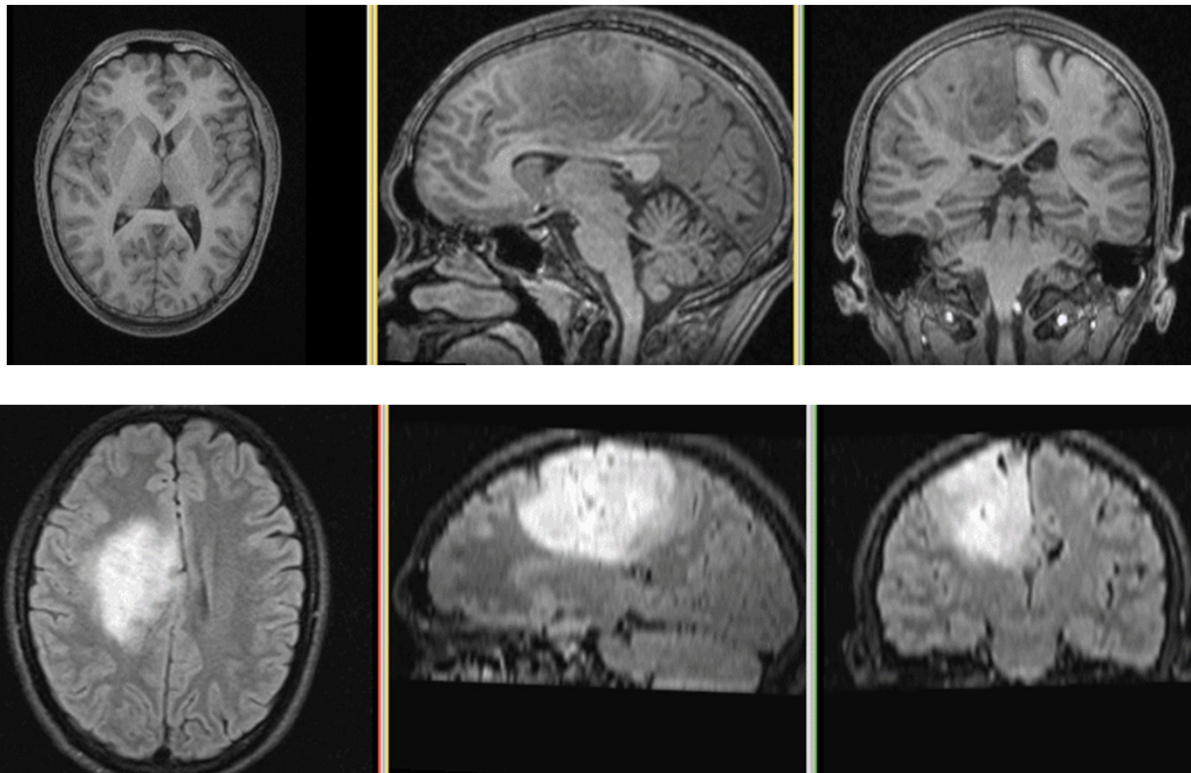
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We have now the DTI in the same orientation and resolution as the T1-resampled reference scan.

For verification of the final registration results:

Choose T1-resampled as the foreground, DTI\_iso\_Xf2 as the background, and toggle the fade slider

animated gifs, view in presentation mode





# Acknowledgements

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